Miscellaneous Paper SL-98-1
January 1998

US Army Corps
of Engineers
Waterways Experiment
Station

Investigation of Concrete from I-20 Near Monroe, Louisiana

by G. Sam Wong

WES

Prepared for Headquarters, U.S. Army Corps of Engineers

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Waterways Experiment Station
3909 Halls Ferry Road
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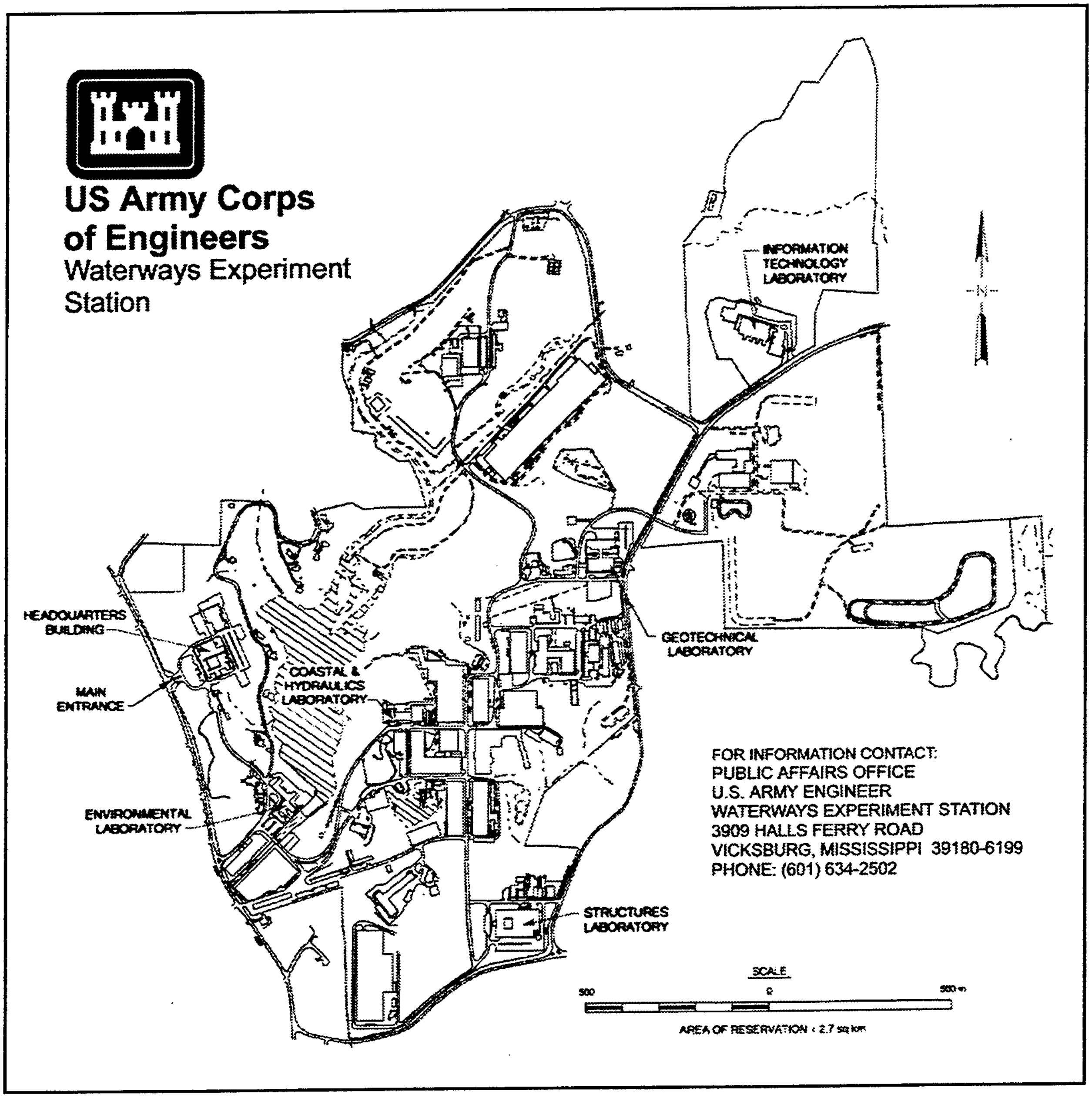
Final report

Approved for public release; distribution is unlimited

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32639



Waterways Experiment Station Cataloging-in-Publication Data

Wong, G. Sam.
Investigation of concrete from I-20 near Monroe, Louisiana / by G. Sam Wong ; prepared for U.S. Army Corps of Engineers.
80 p. : ill. ; 28 cm. — (Miscellaneous paper ; SL-98-1)
Includes bibliographic references.
1. Pavements, Concrete — Louisiana — Testing. 2. Pavements, Flexible — Louisiana — Testing. 3. Concrete — Deterioration — Louisiana — Testing. I. United States. Army. Corps of Engineers. II. U.S. Army Engineer Waterways Experiment Station. III. Structures Laboratory (U.S. Army Engineer Waterways Experiment Station) IV. Title. V. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; SL-98-1.
TA7 W34m no.SL-98-1

Contents

Preface

The research reported in this Miscellaneous Paper was conducted by the Structures Laboratory (SL), U.S. Army Engineer Waterways Experiment Station (WES), under the sponsorship of the Louisiana Transportation Research Center and the Portland Cement Association (PCA Project Index No. 95-04). This investigation was conducted under the general supervision of Messrs. Bryant Mather, Director, SL, and John Ehrgott, Assistant Director, SL. Direct supervision was provided by Dr. Paul F. Mlakar, Chief, Concrete and Materials Division (CMD), SL. Mr. G. Sam Wong, CMD, was the principal investigator of the study and author of this report.

Funds for the publication of the report were provided from those made available for operation of the Concrete Technology Information Analysis Center (CTIAC), SL. This is CTIAC Report No. 92.

The contents of this paper reflect the views of the author, who is responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the views of Louisiana Transportation Research Center or the Portland Cement Association.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Robin R. Cababa, EN.

1 Background

On 2 December 1994, the Louisiana Department of Transportation (LDOT) asked a representative of the U.S. Army Engineer Waterways Experiment Station (WES), Structures Laboratory, to make a field inspection of concrete deterioration on I-20 west of Vicksburg, MS. The inspection, participated in by Messrs. B. Mather, WES; W. H. Temple and N. A. Rabalais, Louisiana Transportation Research Center; and S. W. Foster and P. J. Arena, Federal Highway Administration, took place on 10 January 1995. Following this inspection, Mr. G. S. Wong, Concrete Technology Division (CTD)[1], Structures Laboratory, WES, submitted a proposal to LDOT. This report covers the investigation conducted to determine the probable cause of concrete pavement deterioration in certain lanes of I-20 both east and west of Monroe, LA. Field examination of the pavement by the Department of Transportation and Development (DOTD), State of Louisiana, indicated that concrete near joints was more affected than elsewhere. The concrete in the westbound lanes shows less deterioration than in the eastbound lanes. Some sections of the eastbound lane have been repaired with asphalt.

The concrete represented by the cores was placed as part of projects 451-07-29 east of Monroe and 451-05-0060 west of Monroe during the years 1987 to 1991. The cement came from Lone Star, Cape Girardeau, MO, and Ash Grove, Foreman, AR, respectively, for which typical mill test reports indicated Na_2O_{eq} varying from 0.4 to 0.5 percent. The coarse aggregate was crushed limestone from the Dravo quarry at Smithland, KY. The fine aggregate was natural sand. Class C fly ash from Gifford Hill, Boyce, LA, was used in all of the concrete west of Monroe, represented by cores No. 1 - 6. Fifteen cores were received from the DOTD for use in this investigation. The cores were selected to represent areas of distress as well as non-distressed areas from the different sections of roadway of interest. Each core was given a CTD serial number. The CTD numbers and the accompanying field description of each are provided in Table 1.

[1] The former Concrete Technology Division (CTD) is now designated Concrete and Materials Division (CMD).

2 Evaluation Procedures and Results

Cores were examined and logs made showing the general description of each core. Evaluation specimens also were selected at that time. Evaluations were planned to address the following: (a) the role of alkali- carbonate-rock reaction; (b) the role of alkali-silica reaction; (c) contribution of freezing and thawing action to the deterioration; (d) contribution of fresh concrete properties and construction practices to the deterioration. The evaluation matrix is given in Table 2.

Pulse velocities were determined for 12 of the 15 cores received. Pulse velocities were determined according to American Society for Testing and Materials (ASTM) C 597, "Standard Test Method for Pulse Velocity Through Concrete."

Petrographic examination of the concrete was performed using guidance from ASTM C 856, "Standard Practice for Petrographic Examination of Hardened Concrete." Selected coarse-aggregate particles were extracted from the concrete and examined by X-ray diffraction to determine mineral composition. All photographs were taken of sawed, ground, lapped surfaces prepared essentially as suggested in ASTM C 856 and C 457.

Petrographic examination of the aggregates was performed on coarse-aggregate particles extracted from the concrete as well as from the samples provided. This examination was performed using guidance from ASTM C 295, "Standard Guide for Petrographic Examination of Aggregates for Concrete." All photographs were taken of sawed, ground, and lapped surfaces prepared essentially as suggested in ASTM C 856 and C 457.

Volume stability of the aggregate was determined using ASTM C 586, "Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method)." Small-diameter cylinders were cored from coarse-aggregate particles and subjected to 1N solution of NaOH, and the cylinders were measured periodically to determine changes in length.

Cement-content analyses were performed on four cores. Cores 950617 and 950626 represented concrete from the eastbound lane, and cores 950621 and 950623 represented concrete from the westbound lane. Cement contents were determined using the draft[1] maleic-acid procedure developed by ASTM C 09.69 for inclusion as a revision of "Standard Test Method for Portland-Cement Content on Hardened Hydraulic-Cement Concrete," ASTM C 1084.

Results of Cores

Cores 950623 and 950624 represented concrete in the westbound lane west of Monroe. Some hairline cracks were observed, and they tended to be near the top surface with vertical extent less that 0.05 ft (0.02 m). Both cores were approximately 1 ft (0.3048 m) in length and were of air-entrained concrete. Limestone coarse-aggregate particles were light gray. The logs for cores 950623 and 950624 are shown in Figures 1 and 2, respectively.

Cores 950625, 950626, 950627, and 950628 represent concrete from the eastbound lane west of Monroe. Cores 950625 and 950626 contained reinforcing steel at approximately 0.5-ft (0.15 m) depth. Some lateral cracks were found associated with the reinforcing steel. Core 950627 was intact throughout. Cores 950625, 950626, and 950628 contained some cracking throughout the length of the cores, with cracking more numerous near the surface of the pavement. Cracks were vertical, horizontal, and diagonal. Cores 950625, 950626, and 950628 contained dark-aggregate particles showing some fracturing, as indicated on the logs given in Figures 3 through 6.

Cores 950620, 950619, 950617, 950614, 950616, 950622, and 950618 were from the eastbound lane east of Monroe. The condition of the cores ranged from heavy cracking to no cracks in the concrete, as shown in the core logs given in Figures 7 through 13.

Cores 950621 and 950615 represent concrete in the westbound land east of Monroe. These cores contained very light cracking to no cracks. The coarse aggregate was composed mostly of light-gray limestone particles. The darker limestone coarse-aggregate particles tended to be small. There was a small vertical crack at the bottom of core 950621 associated with a dark limestone particle that contained a reaction rim as well as a fracture in the particle. The concrete was in good condition, as described in the core logs given in Figures 14 and 15.

The pulse velocities were generally above 11,000 ft/sec (3,353 m/sec) with two samples, 950626 and 950628, having lower velocities of 10,600 ft/sec

[1] The specific draft used was Draft #5, 1 June 1994, but the results are regarded as being insignificantly different from those that would have been obtained had the later draft dated 14 November 1995 been followed.

(3,231 m/sec) and 7,560 ft/sec (2,304 m/sec), respectively. The Table 3 tabulates the data for the individual specimens.

The core logs describe the general condition of each core. The following section describes some notable features of the concrete and includes more detailed information on the structure and the composition.

a. 950623 - This core was cut along its entire length to expose the interior concrete. A near-surface vertical crack was associated with subsurface dark-gray coarse-aggregate particles with prominent reaction rims. These particles showed some interior cracks. X-ray diffraction examination of one particle indicated that the particle was composed of a fine-grained dolomitic limestone containing some quartz and clay, as shown in Figure 16. Some interior, randomly oriented incipient cracks were also observed associated with dark-gray coarse-aggregate particles with reaction rims, as illustrated in Figure A1, Appendix A. These cracks were located in the lower portion of the core.

b. 950625 - Vertical cracks from the surface intersected dark-gray coarse-aggregate particles as well as horizontal intermittent fractures, as shown in Figure A2, Appendix A. All fractures could be traced to dark-gray coarse-aggregate particles with dark reaction rims either partially or entirely rimming the particle. No cracking was associated with similar smaller dark coarse-aggregate particles. Cracks in some particles were continuous into the paste while other cracks in the aggregate particles showed no such continuation. The paste was hard and intact.

c. 950626 - This concrete sustained localized damage. A single horizontal crack and some hairline fracturing were observed on a cut section on one side of the slab (Figure A3a, Appendix A). On the reverse side, heavy fracturing of the concrete associated with dark-gray coarse-aggregate particles was observed. Minor cracking at the bottom of the core associated with cracked dark-gray coarse aggregate is illustrated in Figure A3a, Appendix A. Examination of a thin section containing coarse-aggregate particles showed a linear opening along oriented features. The cracks contained no observed reaction products.

d. 950627 - This concrete was intact and generally contains medium-grained light-gray limestone coarse aggregate. The paste was hard and intact, as shown in Figure A4, Appendix A.

e. 950628 - The concrete contained numerous cracks throughout the length of the core. The cracks were vertical, horizontal, and diagonal going through, as well as around, coarse-aggregate particles, as shown in Figures A5a and A5b, Appendix A. There were numerous

dark-gray fine-grained limestone coarse-aggregate particles in the concrete. Some of the pieces were large coarse-aggregate particles and some were small. Cracks were always associated with the larger pieces of aggregate of this nature and were less common with smaller pieces. Many of these pieces of aggregate showed open cracks in the interior of the particle. The X-ray diffraction pattern showed the coarse-aggregate particles to consist of a dolomitic limestone containing some quartz and clay (Figure 17).

f. 950620 - The core was cracked throughout its length. The cracks were randomly oriented. There were numerous dark-gray limestone coarse-aggregate particles with dark reaction rims. The rims exhibited radial cracks that extended into the paste. Aggregate particles with these rims were dolomitic limestone containing quartz and clay. X-ray diffraction patterns are presented in Figures 18 and 19. Figure A6, Appendix A, shows the appearance of these aggregate particles.

g. 950619 - The core was cracked throughout its length. Cracking in the near-surface concrete was more severe as vertical, horizontal, and diagonal cracks were common and associated with dark-gray limestone coarse-aggregate particles (Figure A7, Appendix A). Thin sections of two coarse-aggregate particles were prepared. Particle #A was a light-colored fine-grained limestone consisting of a fine-grained matrix and rhombohedral dolomite crystals. No cracks associated with this particle were observed. Particle #B was a dark-gray fine-grained limestone with a rim around it and was associated with cracking. No difference could be observed between the material in the rim and the interior of the particle. Fine quartz grains were embedded in a calcite matrix.

h. 950617 - This sample consisted of rubble. The core had broken into fragments during the coring process. One large piece was impregnated using an epoxy resin and then cut open for examination. The concrete was highly fractured (Figure A8, Appendix A). There were numerous dark-gray limestone coarse-aggregate particles. Cracks were mostly associated with the larger coarse-aggregate particles. The associated dark-gray coarse-aggregate particles were dolomitic limestone containing some quartz as well as illite (clay-mica). An X-ray diffraction chart showing the relative abundance of the calcite and dolomite is presented in Figure 20.

i. 950614 - Hairline vertical cracks were observed to penetrate approximately 1 in. (25.4 mm) into the concrete. Some incipient fractures were observed in the concrete. The coarse aggregate was primarily a light-colored limestone.

j. 950616 - The surface cracking was light. However, the interior concrete showed an extensive crack system. A vertical crack extended several inches into the interior concrete going through coarse-aggregate particles as well as around them. The vertical cracks intersected horizontal and diagonal cracks (Figures A9a and A9b, Appendix A). The majority of the cracks were associated with cracked dark-gray fine-grained limestone coarse-aggregate particles. Two particles examined by X-ray diffraction were dolomitic limestone with acid-insoluble materials consisting of quartz and clays. Figures 21 and 22 illustrate the relative abundance of the carbonate phases.

k. 950622 - This sample was intact with no visible cracks. The coarse aggregate was light colored and did not contain any reaction rims (Figure A10, Appendix A). A single hairline crack at the bottom of the core, shown in Figure A10, Appendix A, was observed and seems unrelated to dark-gray coarse aggregate.

l. 950618 - This concrete was heavily cracked. Vertical, horizontal, and diagonal cracks were abundant throughout the length of core. The cracking was associated with a large dark-gray limestone coarse-aggregate particle (Figure A11, Appendix A). Fractures were observed in the central portion of the aggregate particle as well as in the rim area of the particle. A specimen of this aggregate particle was cored along the paste-to-aggregate interface and prepared for examination as a ground section. The specimen was impregnated using an epoxy resin to reinforce the sample and minimize possible additional cracking in the preparation process. The specimen showed the propagation of cracks through the interface zone. The cracks were not confined to the interface zone of the aggregate particle as they propagated into the interior of the aggregate particle. The interior portion of the aggregate particle was also cracked. High-resolution elemental analysis using the scanning electron microscope (SEM) and energy dispersive X-ray (EDX) showed no migration of elements in this particular aggregate particle, as illustrated in Figure 27.

m. 950621 - This concrete had some hairline cracks at the surface. One crack penetrated into the interior concrete approximately 1 in. (25.4 mm) and terminated in the paste. The upper portion of the concrete consisted of lighter colored limestone coarse-aggregate particles. The lower portion of the core contained numerous dark-limestone coarse-aggregate particles with dark reaction rims. Some cracks associated with these limestone aggregate particles are shown in Figure A12, Appendix A. The X-ray diffraction pattern of aggregate particle #A, a dark-gray particle with a prominent dark reaction rim, showed it to be pure limestone, as shown in Figure 23. Light-colored brownish limestone with a reaction rim (particle #B) was pure limestone, as identified in Figure 24. The dark-gray particle

with a prominent reaction rim (Figure A12, Appendix A) (particle #C) was a fine-grained dolomitic limestone also containing insoluble material including clays and quartz (Figure 25). A thin section of a near-surface dark-gray fine-grained impure limestone coarse-aggregate particle showed a rim on this aggregate and micro cracks in the rim propagating into the paste. Etching of coarse-aggregate particle using dilute hydrochloric acid showed no relief in the rim area; i.e., the rim was neither more nor less acid soluble than the unaltered rock.

n. 950615 - This concrete contained primarily light-colored limestone coarse-aggregate particles; some dark reaction rims were present on some of the coarse-aggregate particles (Figure A13, Appendix A). When etched with dilute hydrochloric acid, the rims showed no relief. The paste was intact and hard.

Thin sections of the reactive aggregate particle 950629B indicated the rock was composed of euhedral to subhedral crystals of dolomite approximately 0.1-mm nominal size floating in a groundmass of calcite and other mineral matter. Crystals in the groundmass were less than 0.015-mm nominal size. Reactive particle 950630B contained subhedral dolomite crystals with a nominal size of 0.04 mm in a fine-grained groundmass. Both were impure dolomitic limestones.

Rock-cylinder expansion measurements indicated that some of the aggregate particles were highly reactive when stored in sodium hydroxide in accordance with ASTM C 586. Figures 28 and 29 show expansion data up to 64 days. The specimens were immersed in water for 7 days and showed no change in length. Specimens from both limestone samples included aggregate materials that expanded significantly. Sample 950629 showed immediate expansion and rose to above 3 percent at 35 days; measurements were terminated for these particular specimens as they began to fall apart. Sample 950630 yielded specimens that expanded to above 0.4 percent in 64 days in sodium hydroxide. Analysis of a highly expansive particle in 950629 (particle B) indicated the sample to be composed of dolomitic limestone containing some quartz and clay. No reaction products were detected by X-ray diffraction analysis, as shown in Figure 26.

Cement-content analysis indicated that three samples contained 420 to 438 lb/yd^3 (249 to 260 kg/m^3), and one sample had a cement content of over 600 lb/yd^3 (356 kg/m^3). The results are shown in the Table 4.

Results of Samples

All cement paste was hard and intact. No evidence of sulfate attack was detected. Although ettringite crystals in voids are not necessarily evidence of sulfate attack, the absence of ettringite in the fracture surfaces and in voids is a positive indication of the absence of sulfate attack.

There was no scaling of the concrete observed, the concrete was adequately air entrained, and the typical freezing and thawing damage caused when paste is critically saturated was not observed. Generally, when the freezing isotherm goes through the concrete, it will create stresses normal to the surface resulting in cracking that tends to be subparallel to parallel to the surface of the concrete. Cracking in the cores that contained cracks tended to be random in orientation. Based on these observations, it was regarded as unnecessary to conduct quantitative work according to ASTM C 457 to develop data on the air-void system of the concrete.

Hairline cracks with only near-surface penetration are most likely drying shrinkage cracks caused by loss of the moisture from the concrete. This was observed in most of the cores examined.

Alkali-silica reaction was minimal. Alkali-silica gel was observed only in isolated voids. No alkali-silica reaction products were observed in the cracks in the concrete.

Carbonate-rock reaction was common throughout the pavement in all sections. The amount of deleteriously reactive aggregate varied from location to location from and within a location. There is significant evidence that much of the cracking is related to dark-gray dolomitic limestone coarse-aggregate particles. Many of the cracks seem to propagate from these coarse-aggregate particles.

It is believed that this reaction is continuing in the pavement in some locations as some of the aggregate particles show major fracturing of the particle itself and fractures into the adjacent paste and concrete. Other particles are only minimally cracked, and it is likely that these have the potential to continue to experience disruptive volume change. In other places, there was no surface expression of deterioration but some reactive aggregates were identified deeper in the pavement with associated cracks. This may reduce the service life of the pavement section in which this is present.

Not all of the cracking is solely attributed to the carbonate-rock reaction. In some areas where cracking is severe, there does not appear to be sufficient reactive aggregates to suggest that this reaction is solely responsible for the deterioration. Because deterioration seems to be observed first along joints, pavement edges, and approach ramps to bridges, the weakening of the concrete by carbonate-rock reaction is most likely aggravated by loading due to traffic.

3 Conclusions and Recommendations

Deterioration of the concrete is evidenced by cracking and raveling of the pavement. In this investigation, we have identified some deterioration in which there is minimal evidence at the concrete surface. Where there is disruption of the paste, incipient cracks present in the concrete will open during continued loading. It is also envisioned that the cracks can be filled with water and during freezing, wedging action could work to increase damage to the concrete. It is regarded as unlikely that freezing and thawing effects could do more than aggravate deterioration of already distressed concrete. The location is in the moderate weathering region designated in Figure 1 of ASTM C 33, "Standard Specification for Concrete Aggregates." In spite of this categorization, bridge-railing concrete on I-20 in Mississippi developed popouts due to freezing of critically saturated concrete containing porous-chert aggregate particles.

There were numerous dolomitic limestone particles in the smaller size fraction which when observed individually in the concrete appeared to have limited effect on the cracking of the concrete. When present in substantial numbers, deterioration of concrete was observed.

Pulse velocities of the cores, in general, can be separated into categories where above 12,000 ft/sec (3,658 m/sec) is considered good and that below is questionable. There is a lack of correlation in the observed information. The limited pulse-velocity information is not sufficient to categorize the integrity of the various concretes represented. Some of the cores containing cracks had relatively high pulse velocities.

Many of the coarse-aggregate particles reacted in the concrete. Reaction rims partially or entirely surrounded the particles. Not all of the coarse-aggregate particles reacted as some did not have reaction rims. Not all of the dark-gray particles that reacted were expansive. The reactive particles that were identified as expansive were particles of impure dolomitic limestone. Nonreactive dark-gray particles were pure limestone.

Traditional reactive carbonate-rock aggregates have a composition similar to that which is described as expansive in this concrete. There is no doubt that this concrete underwent internal expansion and cracking associated with alkali-carbonate rock reaction (ACR) involving dolomitic carbonate rock with the composition and texture of dolomites that have been identified at other places as associated with expansive deterioration of concrete. In many such cases, the deterioration is believed to have been initiated by a chemical reaction that alters the mineral dolomite ($CaCO_3 \cdot MgCO_3$) to $CaCO_3$ (calcite) and $Mg(OH)_2$ (brucite). The CO_2 in the $MgCO_3$ typically combines with alkali and later with the calcium in the pore fluid of the concrete. It has been suggested that the expansive force is due to reaction of the alkali with clay minerals in the matrix of the rock. Since in the present case, no evidence of alteration of the dolomite (i.e., no production of $Mg(OH)_2$ (brucite)) and no migration of elements across the coarse-aggregate paste interface were found, it is assumed that the source of the expansive force that produced the cracks radiating from the reactive coarse-aggregate particles is a chemical reaction and expansion of the clay minerals in the matrix. As noted, no expansion of the rock cylinders taken from the samples of crushed limestone was observed when soaked in water before being exposed to sodium hydroxide (NaOH), but in some cases, a large expansion was noted quite soon when exposed to NaOH.

Carbonate-rock reaction may continue indefinitely or until the moisture content falls below a certain level at which the reaction can no longer continue, since it is a chemical reaction involving diffusion of ions in the pore fluid of the concrete.

Bridge decks were treated as necessary with calcium magnesium acetate (CMA) as a deicing agent. ACR may be accelerated by the addition of sodium chloride, which is a common deicing agent. It is not expected that CMA would cause acceleration of the ACR.

The reactive aggregate particles were found in both aggregate samples examined (950629 and 950630). The testing of the aggregate was limited to particles large enough to obtain test specimens. The testing suggests the presence of alkali-carbonate reactive aggregate, but is not an indication of the amount of deleteriously reactive aggregate nor the reactiveness of the aggregate source.

Cement content is a variable in the concrete, but it does not seem to affect the quality of the concrete or the reaction in this situation.

Where the concrete contains fly ash, the measured cement contents are biased towards higher values, particularly if the concrete is old, so that the fly ash hydration is advanced, or if the concrete contains Class C fly ash, or both. All concrete from west of Monroe contained some fly ash.

The insoluble residue of the cement was analyzed in either duplicate or triplicate. This is the part of the analysis that appears to be most prone to

error; however, replication was good enough to indicate that the value for sample 950621 was significantly higher than the cement contents of the other three cores when means were compared in an analysis of variance procedure.

The deterioration of the concrete, samples of which were examined, is believed to be the consequences of a chemical reaction involving a type of rock present in the coarse aggregate that was used. The coarse aggregate is a carbonate rock that comes in a variety of types--both light colored and dark colored, with little or no quartz or clay (insoluble residue), and ranging from pure limestone (no significant amount of magnesium carbonate) to dolomite (about equal amounts of calcium and magnesium carbonate). The chemical reaction causes rims to form on some of these varieties, mostly the dark-colored ones, some dolomitic, some pure limestone. However, unless the rock is not only dark but also dolomitic and with a significant amount of quartz and clay, the rim-forming reaction does not seem to be accompanied by physical distress in the concrete. In the two samples of rock tested, only 2 of 12 and 2 of 10 showed expansion when evaluated as rock cylinders in accordance to ASTM C 586. The physical distress is manifested by cracking radiating from affected coarse-aggregate particles. The literature has suggested that such internal expansion can result from either the de-dolomitization reaction or as a secondary consequence of breakdown in the rock that allows fluid access to the included clay and the swelling of the clay. No evidence of de-dolomitization was developed in the work that was done. No brucite ($Mg(OH)_2$) nor any migration of elements across the paste-coarse aggregate interface was detected. It may, therefore, be that the expansive force is produced by the swelling of the clay in the rock. It is reported that the cement used was low alkali; this may not preclude deleterious alkali-carbonate rock reaction since some scenarios for such reaction contemplate regeneration rather than sequestration of the alkali that participates in the reaction.

Deterioration of the pavement is related to the presence and abundance of deleterious reactive carbonate-rock coarse-aggregate particles reacting with the alkalies in the cement. Some of the pavement not already showing distress may continue to deteriorate, causing future pavement failure in areas not currently showing such distress. To identify portions of pavement with potential for deterioration would require an extensive coring program and the petrographic examination of the cores to identify the presence and absence of deleterious reactive aggregates. This may not be practical as there is variability within cores as well as between the cores examined, which was demonstrated during this investigation.

It is expected that the pavement will continue to be weakened by this reaction and that deterioration will be aggravated by traffic. The degree to which traffic aggravates the deterioration may well be influenced by differences from location to location in the bearing capacity of the foundation. As the pavements deteriorates, those areas should be removed and replaced.

It is recommended that this aggregate type be avoided in planning for future portland-cement concrete construction or precautions should be taken to minimize the alkali-carbonate rock reaction in the concrete if it is necessary to use this rock for aggregate. U.S. Army Corps of Engineers test data on this rock are given in Appendix B.

References

American Society for Testing and Materials. (1995). *1995 Annual Book of ASTM Standards*. Philadelphia, PA.

Designation C 33, "Standard specification for concrete aggregates."

Designation C 295, "Standard guide for petrographic examination of aggregates for concrete."

Designation C 457, "Standard specifications for microscopial determination of parameters of the air-void system in hardened concrete."

Designation C 586, "Standard test method for potential alkali-reactivity of carbonate rocks for concrete aggregates (rock cylinder method)."

Designation C 597, "Standard test method for pulse velocity through concrete."

Designation C 856, "Standard practice for petrographic examination of hardened concrete."

Designation C 1084, "Standard test method for portland-cement content of hardened hydraulic-cement concrete."

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number) L-1
5. NAME OF DRILLER
6. DIRECTION OF HOLE
   VERTICAL ☐ INCLINED ☐ ________ DEG. FROM VERT
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 0.9 feet
10. SIZE AND TYPE OF BIT 6"
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING
19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Drag finished surface HL incipient crack to 0.05-ft.			
-0.9	0.9		EOB 0.90-ft. Flat asphalt interface 1.5-in. max size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950623			

Figure 1. Log of core 950623

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-2	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ____ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 1.1 feet	19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine grooved surface HL incipient crack No vertical extension			
-1.1	1.1		EOB 1.10-ft. Flat asphalt interface 1.5-in. max size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950624 Ls CA tend to be lighter color w/no reaction rims			

Figure 2. Log of core 950624

DRILLING LOG | DIVISION | INSTALLATION Louisiana Hwy Dept. | SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores

2. LOCATION (Coordinates or Station)

3. DRILLING AGENCY

4. HOLE NO. (As shown on drawing title and file number) L-3

5. NAME OF DRILLER

6. DIRECTION OF HOLE
VERTICAL ☐ INCLINED ☐ ________ DEG. FROM VERT

7. THICKNESS OF OVERBURDEN

8. DEPTH DRILLED INTO ROCK

9. TOTAL DEPTH OF HOLE 1.15 feet

10. SIZE AND TYPE OF BIT 6"

11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)

12. MANUFACTURER'S DESIGNATION OF DRILL

13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED

14. TOTAL NUMBER CORE BOXES

15. ELEVATION GROUND WATER

16. DATE HOLE | STARTED | COMPLETED

17. ELEVATION TOP OF HOLE

18. TOTAL CORE RECOVERY FOR BORING

19. SIGNATURE OF INSPECTOR

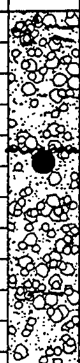
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine grooved surface HL incipient crack Break at cast of rebar Numerous incipient fractures upper 0.5-ft. Some near 0.9-ft.			
-1.15	1.15		EOB 1.15-ft. Asphalt interface 1.5-in. max size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950625 Incipient fractures associated with numerous dark Ls CA w/ reaction rims, particles tend to be fractured			

Figure 3. Log of core 950625

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-4	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ______ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 1.1 feet	19. SIGNATURE OF INSPECTOR

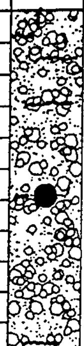
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine grooved surface HL incipient crack 1 3/8-in. steel bar (epoxy coated) incipient fracture			
-1.1	1.10		EOB 1.10-ft. Asphalt interface 1.5-in. max size Ls CA crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950626 Incipient fractures associated with large dark Ls CA w/ reaction rims, fractured			

Figure 4. Log of core 950626

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-5	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ____ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 1.15 feet	19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine grooved surface			
-1.15	1.15		EOB 1.15' Asphalt Interface 1.5-in max. size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950627			

Figure 5. Log of core 950627

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-6	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ______ DEG. FROM VERT	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 1.1 feet	19. SIGNATURE OF INSPECTOR

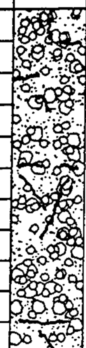
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine grooved surface Map crack pattern Fractures generally around aggregate Some fractures through CA			
-1.1	1.1		EOB 1.10-ft. Asphalt interface 1.5-in. max size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950628			

Figure 6. Log of core 950628

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number) L-7
5. NAME OF DRILLER
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ____ DEG. FROM VERT
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 1.1 feet
10. SIZE AND TYPE OF BIT 6"
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING
19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine grooved surface Surface cracked to 0.1-ft.			
-1.1	1.1		Asphalt interface 1.5-in. max size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950620 Reaction rims around dark CA Near surface voids above CA			

Figure 7. Log of core 950620

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-8	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ________ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 1.1 feet	19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine grooved surface Numerous incipient fractures near surface 0.2-ft			
-1.1	1.1		EOB 1.10-ft. Asphalt interface 1.5-in. max size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950619 Numerous reaction rims on CA, fractures are plentiful in some CA w/ reaction rims			

Figure 8. Log of core 950619

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS
1. PROJECT I-20 Cores		10. SIZE AND TYPE OF BIT 6"	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	L-9	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ____ DEG. FROM VERT		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED / COMPLETED
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE 0.2 feet		19. SIGNATURE OF INSPECTOR	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Rubble			
-0.2	0.2		EOB Asphalt interface 1.5-in. max size Ls CA, crushed Siliceous FA, natural Air Entrained Reaction rims on CA observed Some CA are fractured CTD #950617			

Figure 9. Log of core 950617

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number) L-10
5. NAME OF DRILLER
6. DIRECTION OF HOLE
   VERTICAL ☐ INCLINED ☐ ________ DEG. FROM VERT
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 0.9 feet
10. SIZE AND TYPE OF BIT 6"
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING
19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished top surface Incipient fracture			
-0.9	0.9		EOB 0.9-ft Asphalt surface 1.5-in maximum size Ls CA, crushed (mostly 1-in and smaller) Siliceous FA, natural No segregration Good consolidation Air entrained CTD #950614 Numerous reaction rims on CA, some aggregate are fractured w/cracks extending into paste			

Figure 10. Log of core 950614

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-11	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ______ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 1 feet	19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine surface Incipient fracture Incipient fracture			
-1	1.0		EOB 1.0-ft Asphalt interface 1-in maximum size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950616 Numerous reaction rims on CA, some aggregate are fractured w/cracks extending into paste			

Figure 11. Log of core 950616

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-12	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ____ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 0.9 feet	19. SIGNATURE OF INSPECTOR

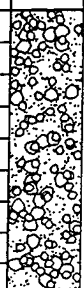
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished surface			
-0.9	0.9		EOB 0.9-ft Asphalt interface 1-in maximum size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air Entrained CTD #950622 Few dark pieces of CA w/ reaction rims, mostly light color Ls pieces			

Figure 12. Log of core 950622

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT 6"
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-13	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ________ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 0.9 feet	19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine surface Incipient fractures through out			
-0.9	0.9		EOB 0.9-ft New break 1.5-in maximum size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air Entrained CTD #950618 Numerous reaction rims on CA, some aggregates are fractured w/cracks extending into paste			

Figure 13. Log of core 950618

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY
4. HOLE NO. (As shown on drawing title and file number) L-14
5. NAME OF DRILLER
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ________ DEG. FROM VERT
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 1 feet
10. SIZE AND TYPE OF BIT 6"
11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING
19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOV-ERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Tine surface			
-1	1.0		EOB 1.0-ft Asphalt interface 1-in maximum size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air Entrained CTD #950621 Mostly light colored Ls CA Some incipient fractures near bottom of core associated w/ dark Ls particles w/reaction rims and fractures			

Figure 14. Log of core 950621

DRILLING LOG	DIVISION	INSTALLATION Louisiana Hwy Dept.	SHEET 1 OF 1 SHEETS

1. PROJECT I-20 Cores	10. SIZE AND TYPE OF BIT
2. LOCATION (Coordinates or Station)	11. DATUM FOR ELEVATION SHOWN (TBM OR MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL
4. HOLE NO. (As shown on drawing title and file number) L-15	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE VERTICAL ☐ INCLINED ☐ ________ DEG. FROM VERT	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 0.9 feet	19. SIGNATURE OF INSPECTOR

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc. if significant)
0	0.0		Finished surface			
-0.9	0.9		EOB 0.9-ft Asphalt interface 1.5-in maximum size Ls CA, crushed Siliceous FA, natural No segregation Good consolidation Air entrained CTD #950615 Some reaction rims on CA, mostly light colored CA particles, darker pieces tend to be small			

Figure 15. Log of core 950615

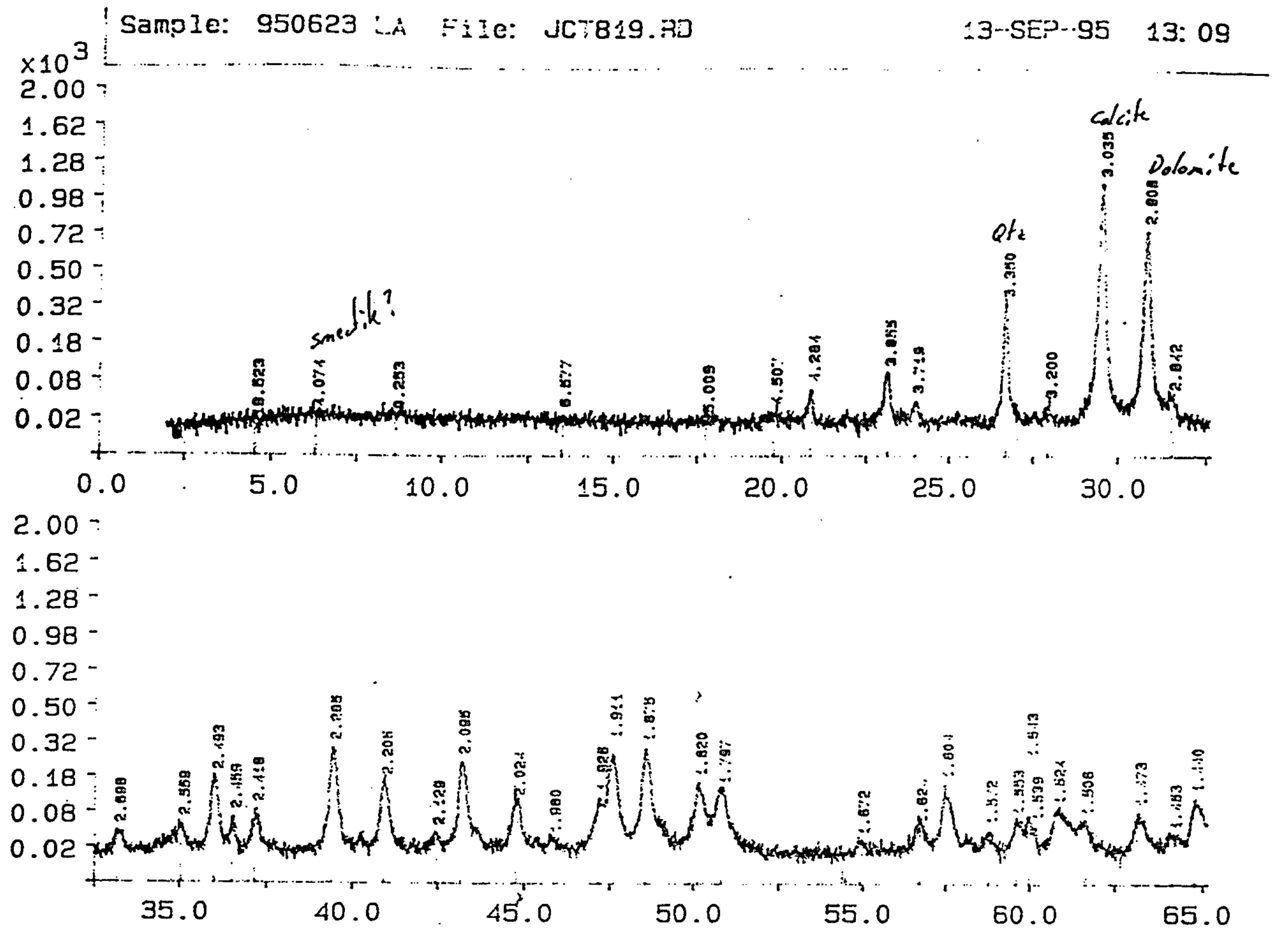


Figure 16. X-ray diffraction pattern of reactive coarse-aggregate particle from core 950623

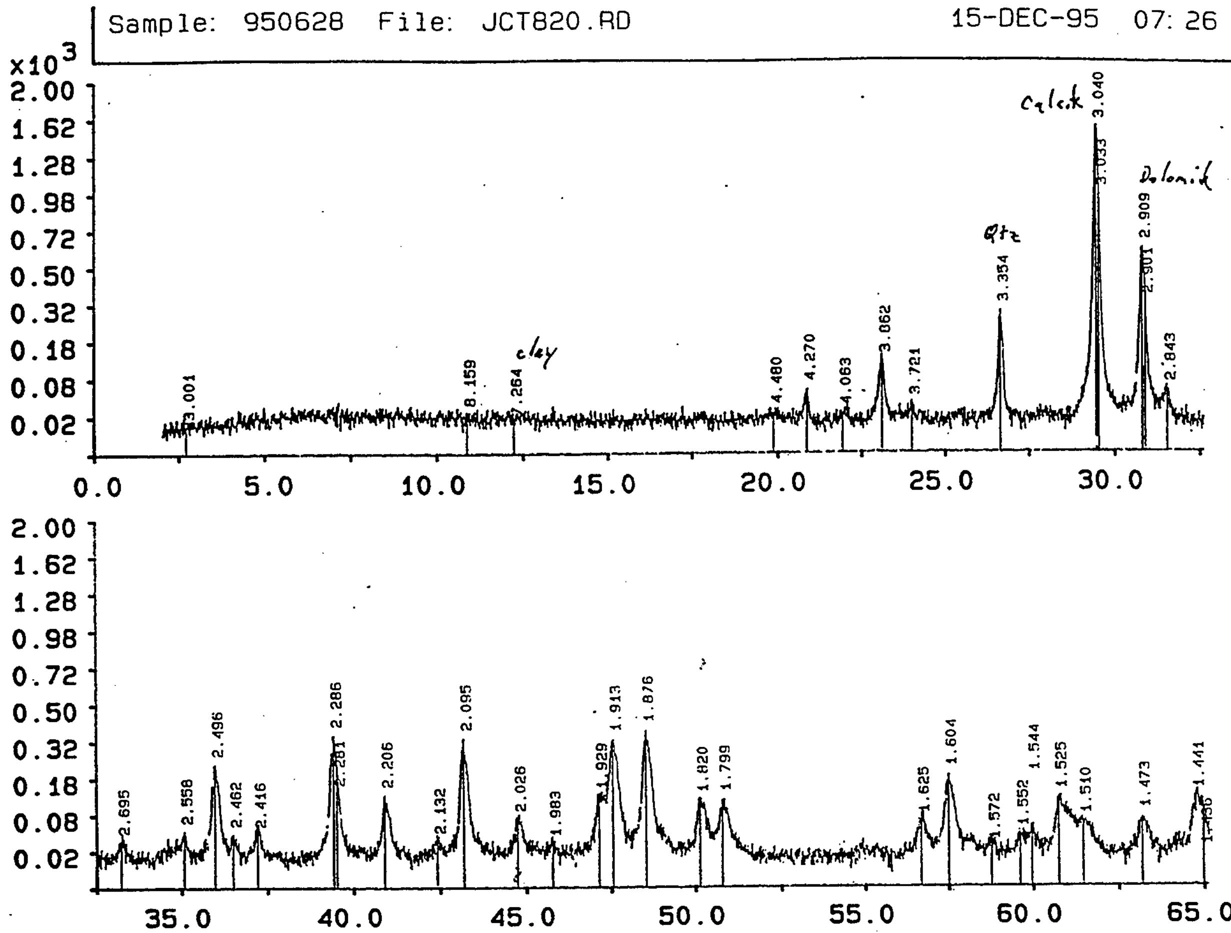


Figure 17. X-ray diffraction pattern of reactive coarse-aggregate particle from core 950628

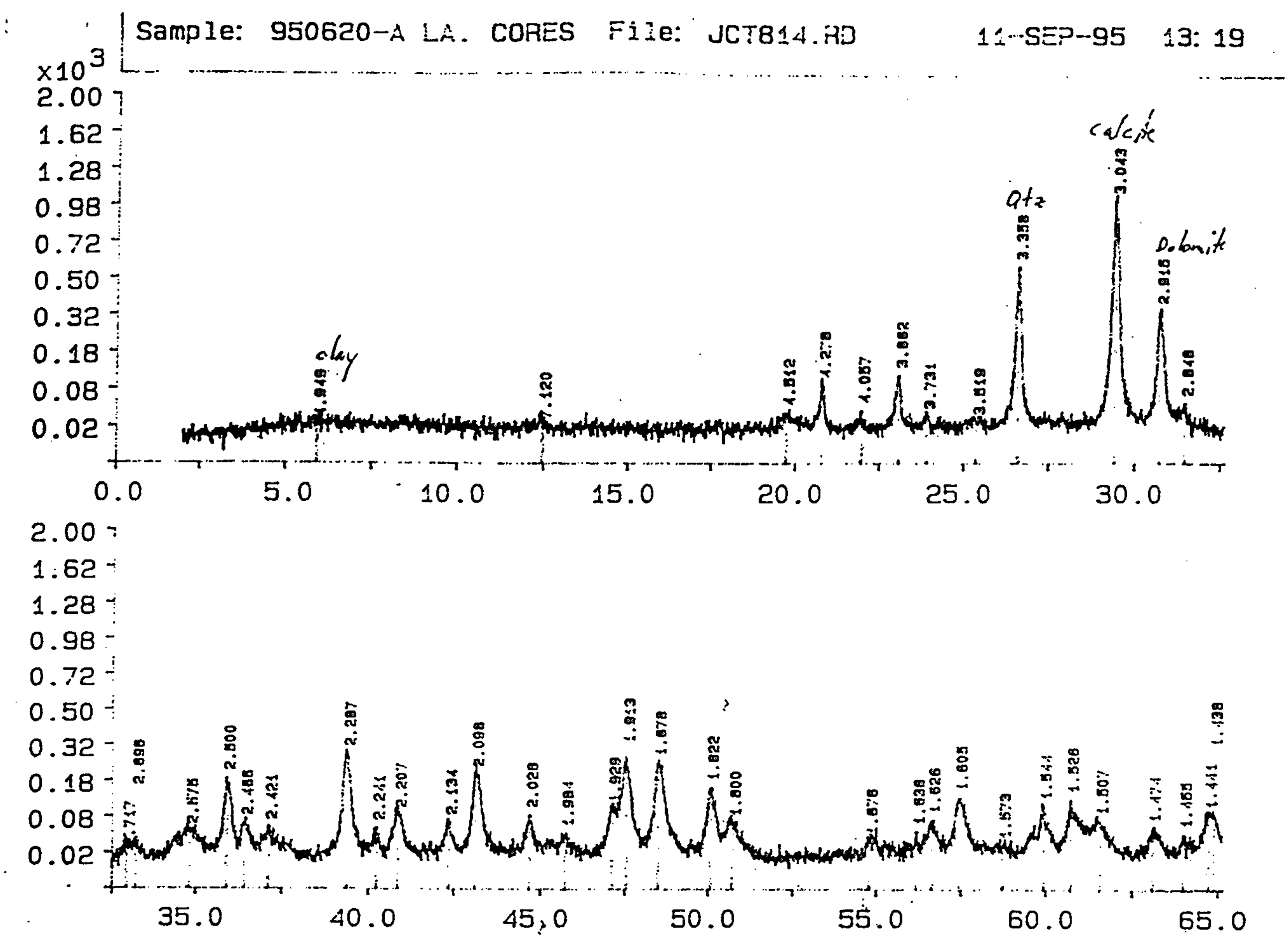


Figure 18. X-ray diffraction pattern of reactive coarse-aggregate particle #A from core 950620

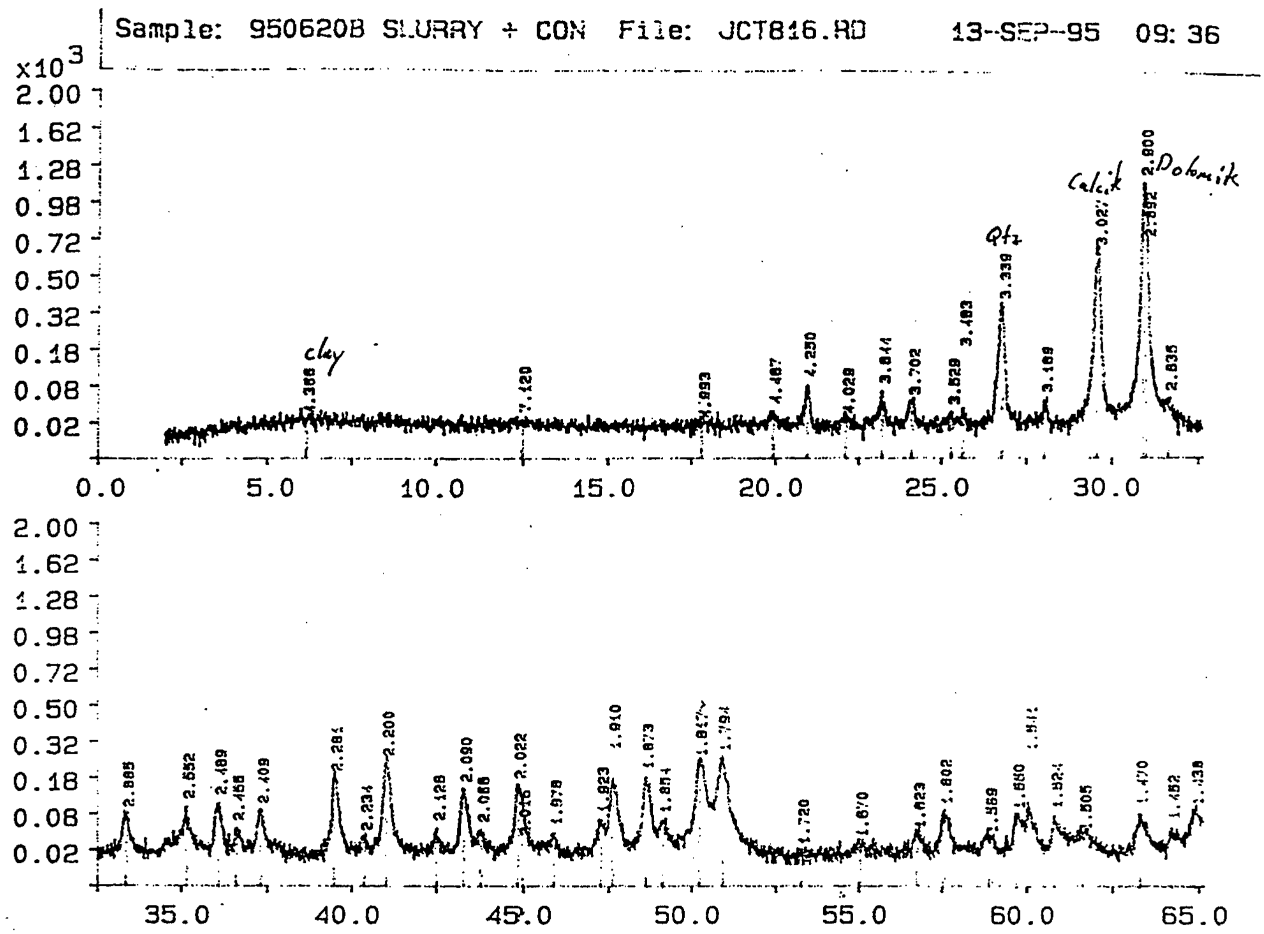


Figure 19. X-ray diffraction pattern of reactive coarse-aggregate particle #B from core 950620

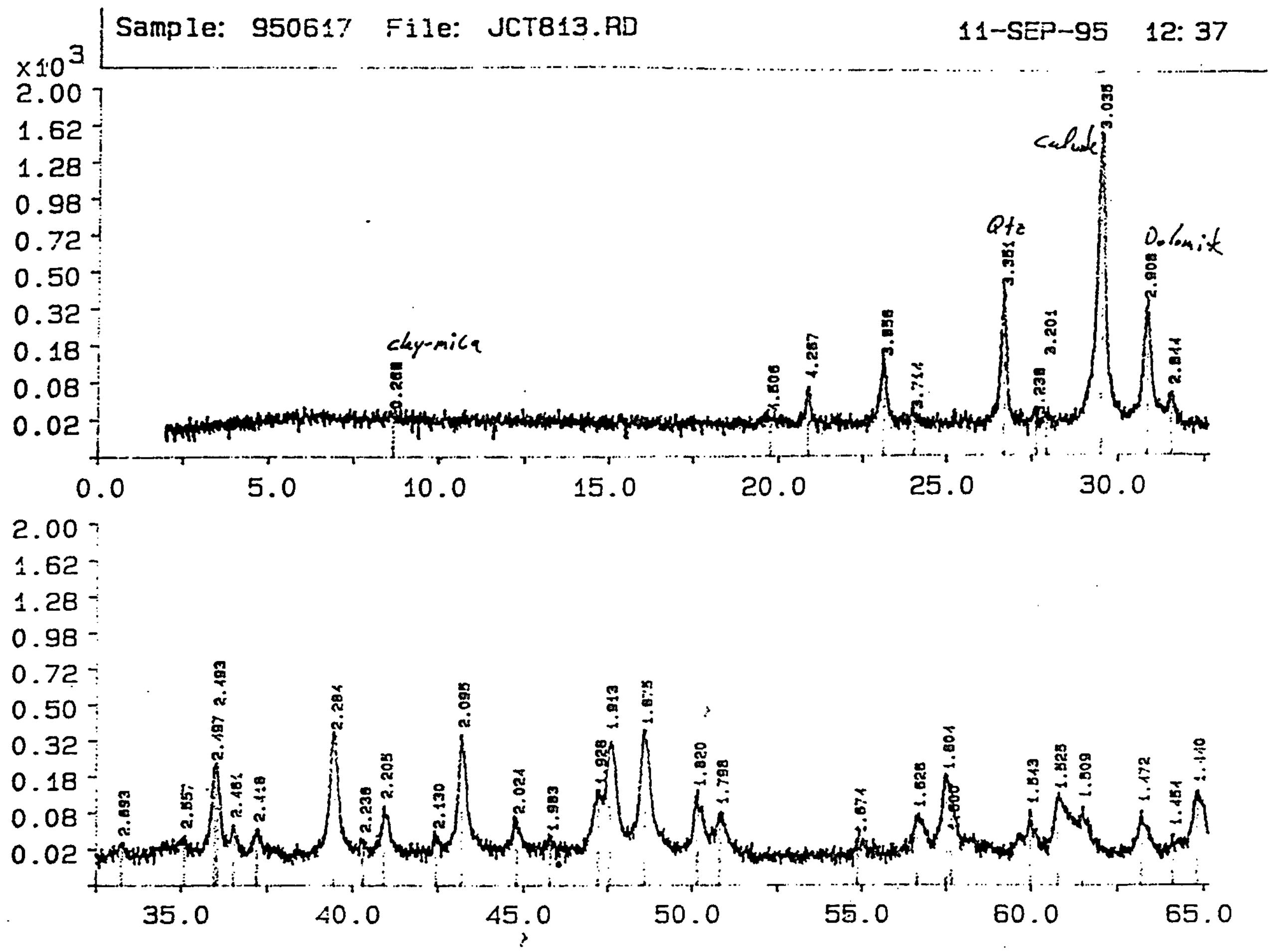


Figure 20. X-ray diffraction pattern of reactive coarse-aggregate particle from core 950617

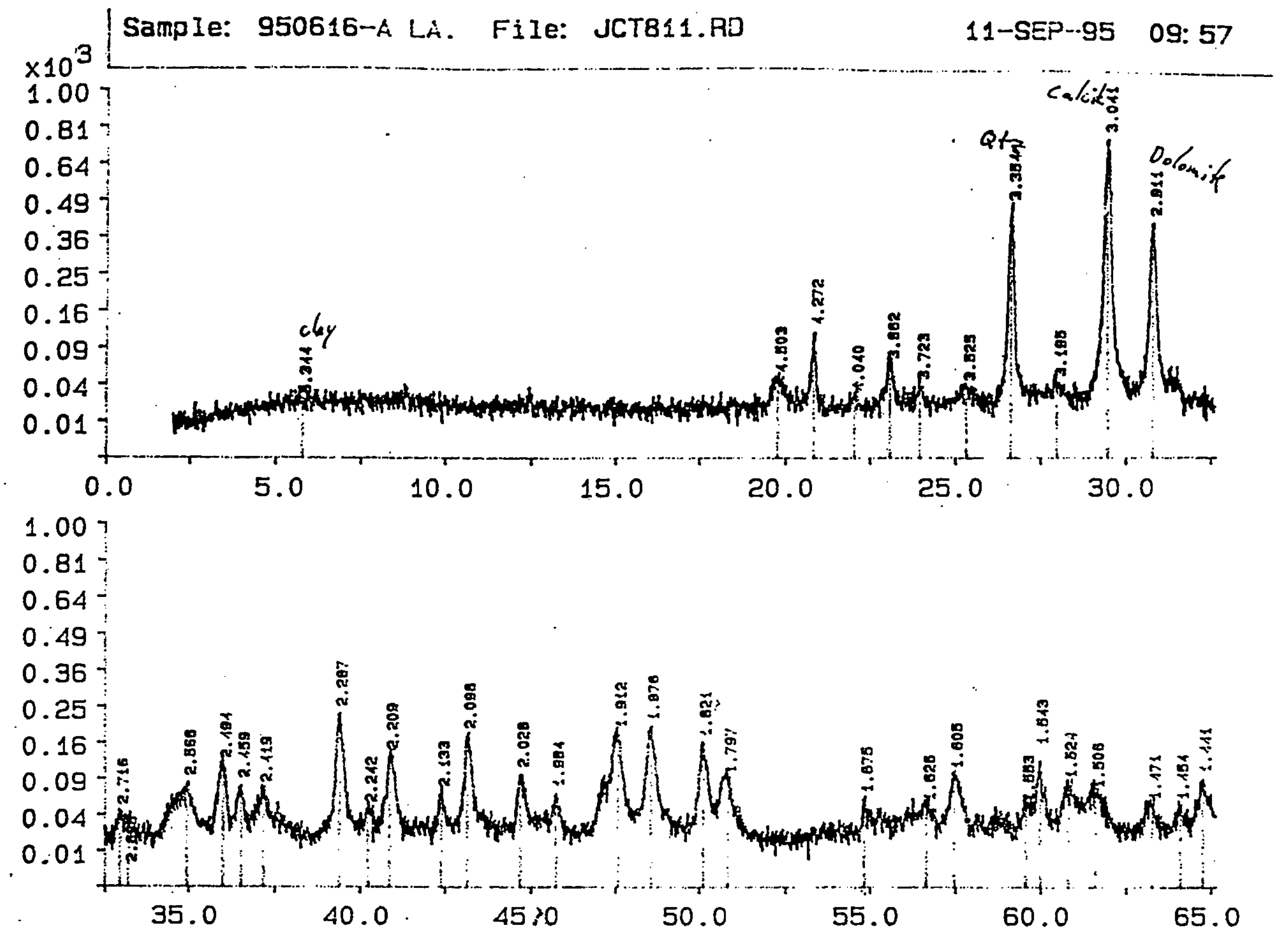


Figure 21. X-ray diffraction pattern of reactive coarse-aggregate particle #A from core 950616

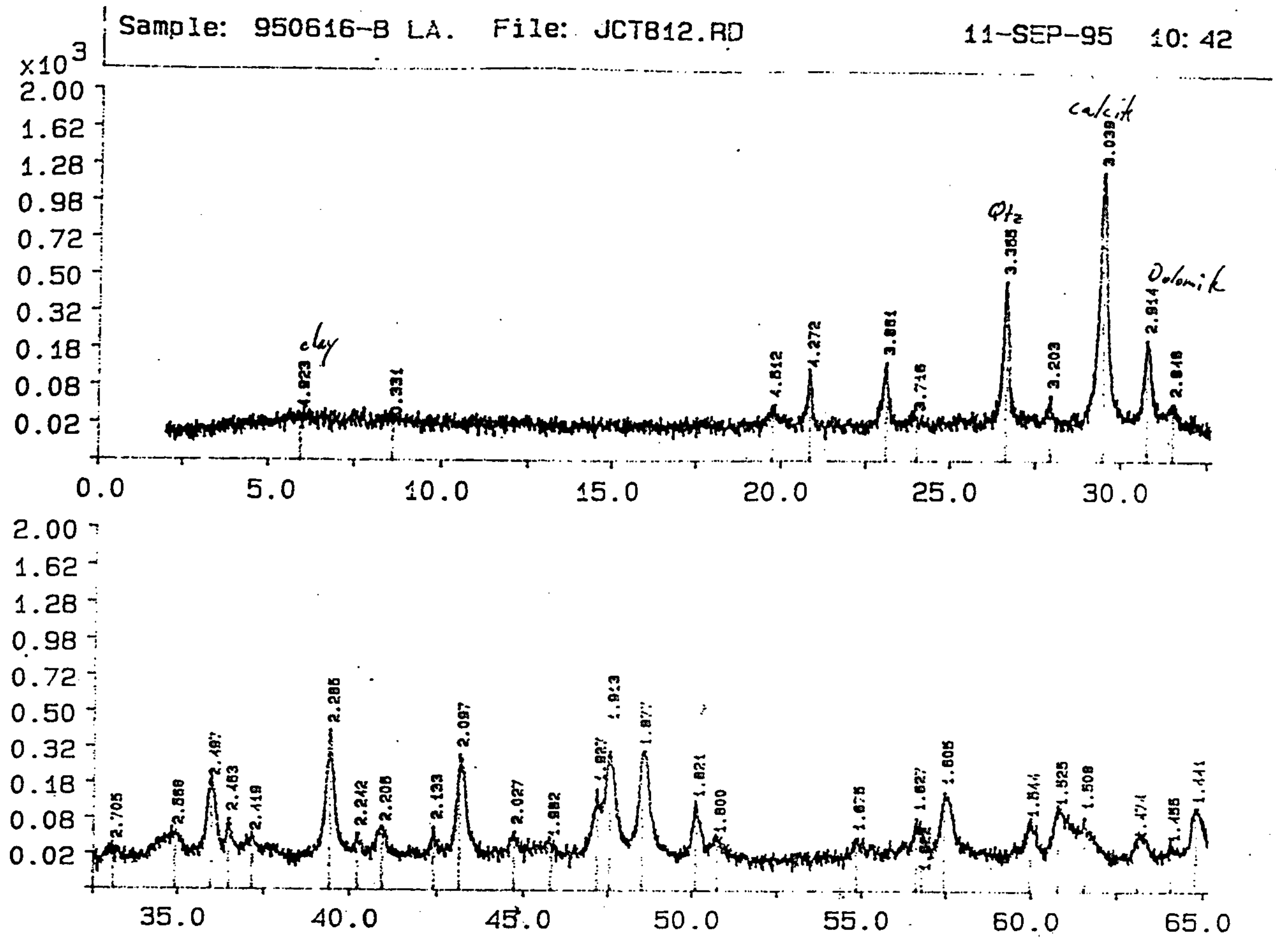


Figure 22. X-ray diffraction pattern of reactive coarse-aggregate particle #B from core 950616

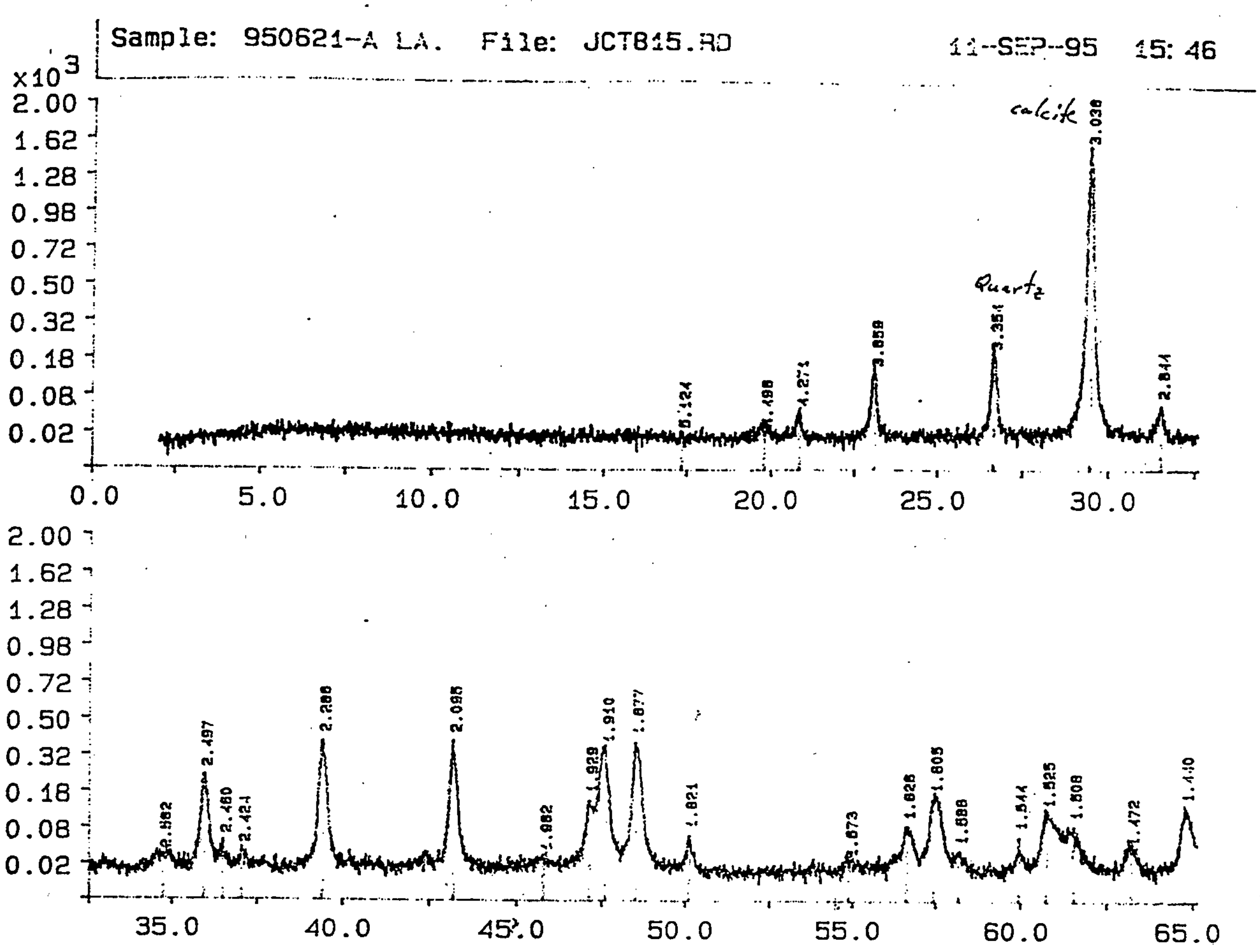


Figure 23. X-ray diffraction pattern of non-expansive reactive coarse-aggregate particle #A from core 950621

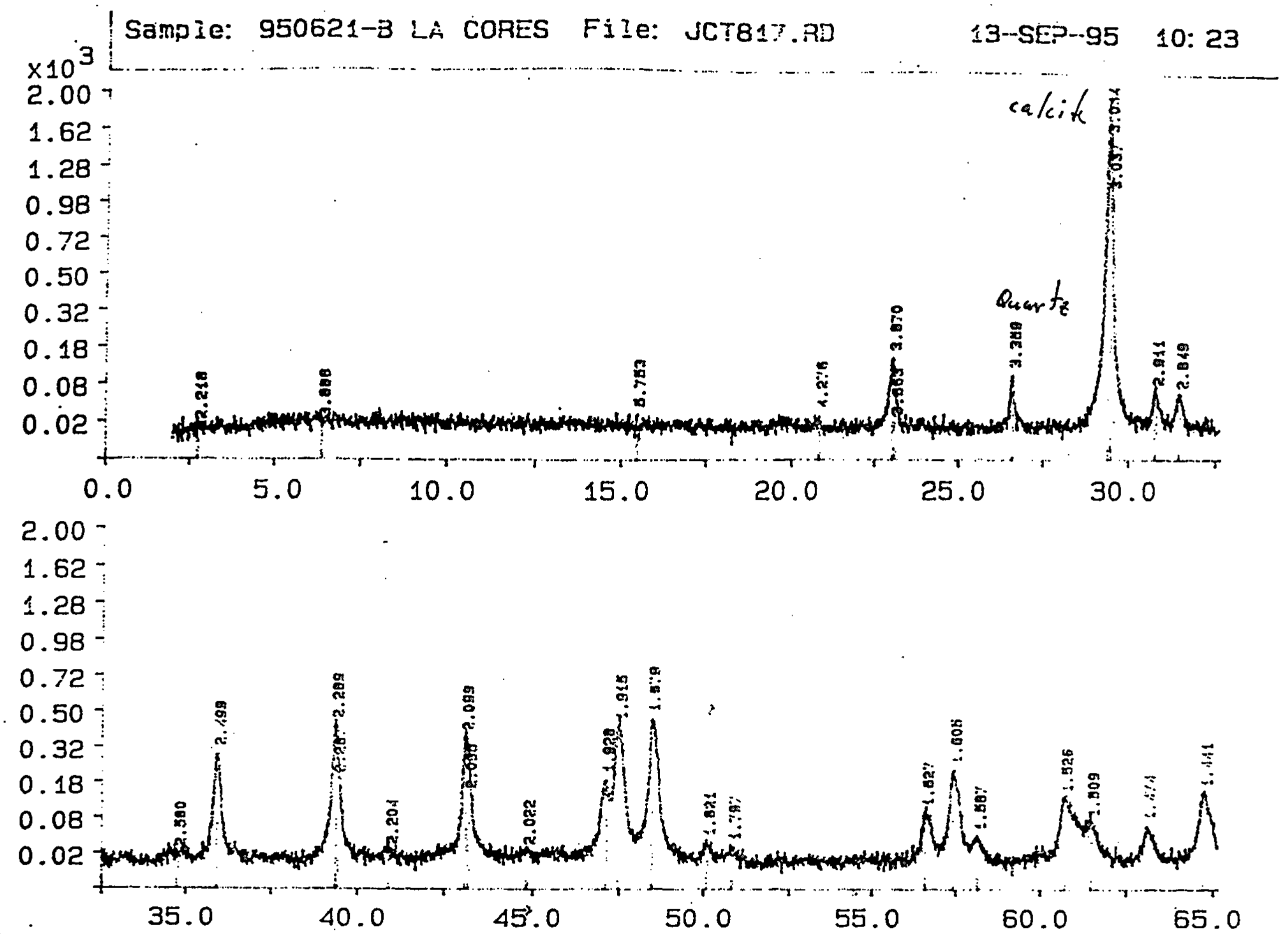


Figure 24. X-ray diffraction pattern of non-expansive reactive coarse-aggregate particle #B from core 950621

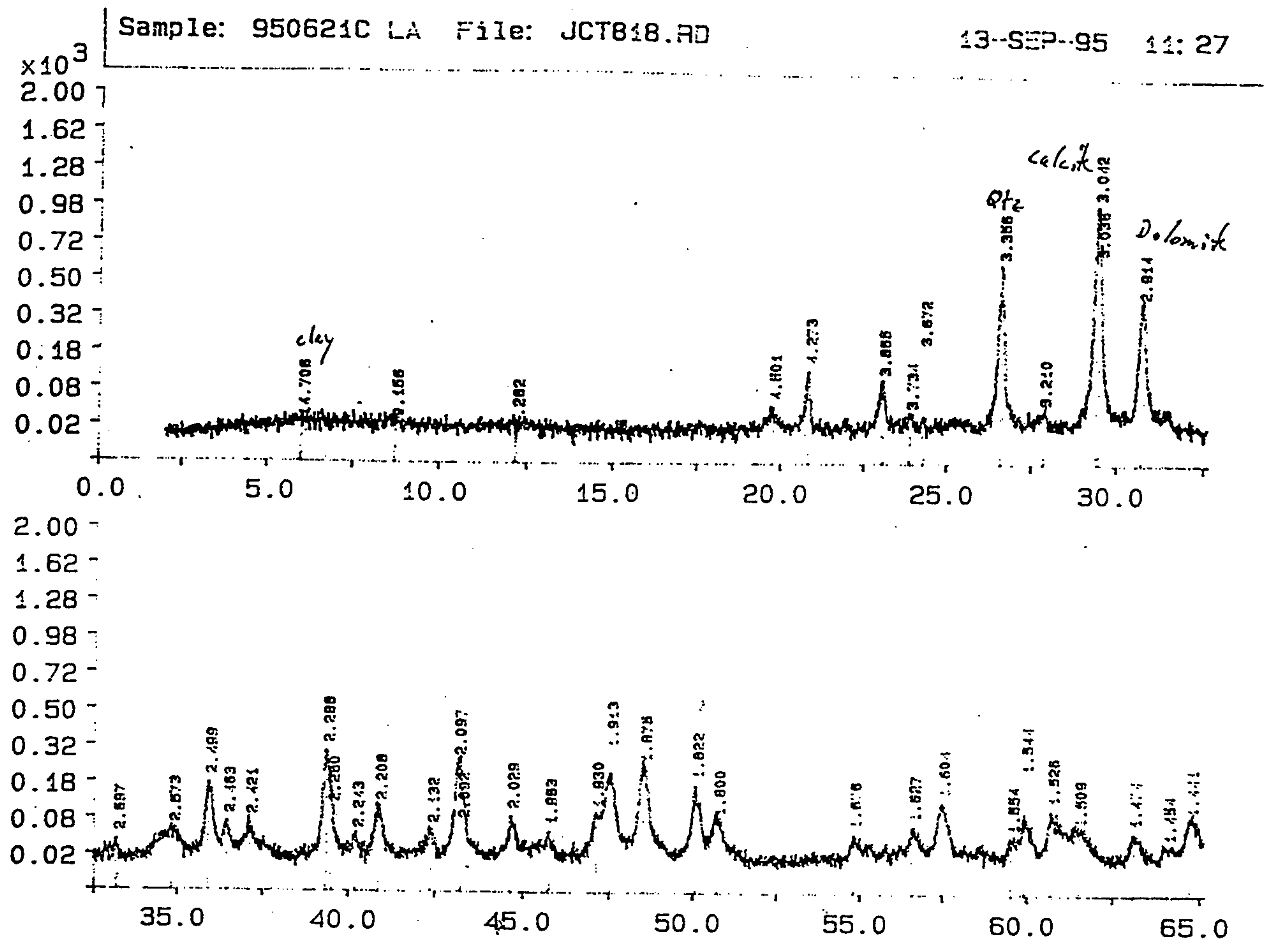


Figure 25. X-ray diffraction pattern of expansive reactive coarse-aggregate particle #C from core 950621

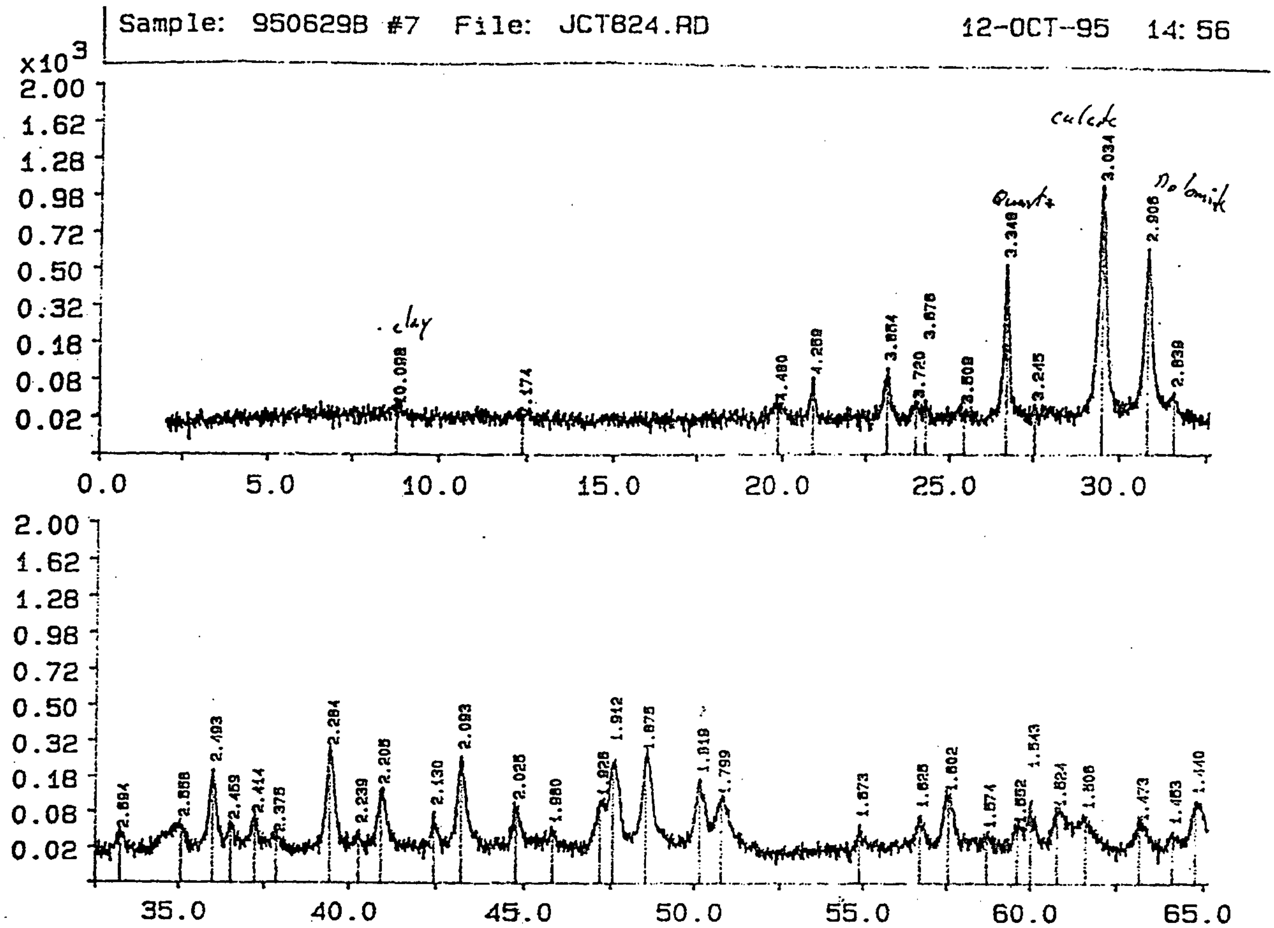


Figure 26. X-ray diffraction pattern of highly reactive coarse-aggregate particle #B from limestone sample 950629 after treatment in sodium hydroxide

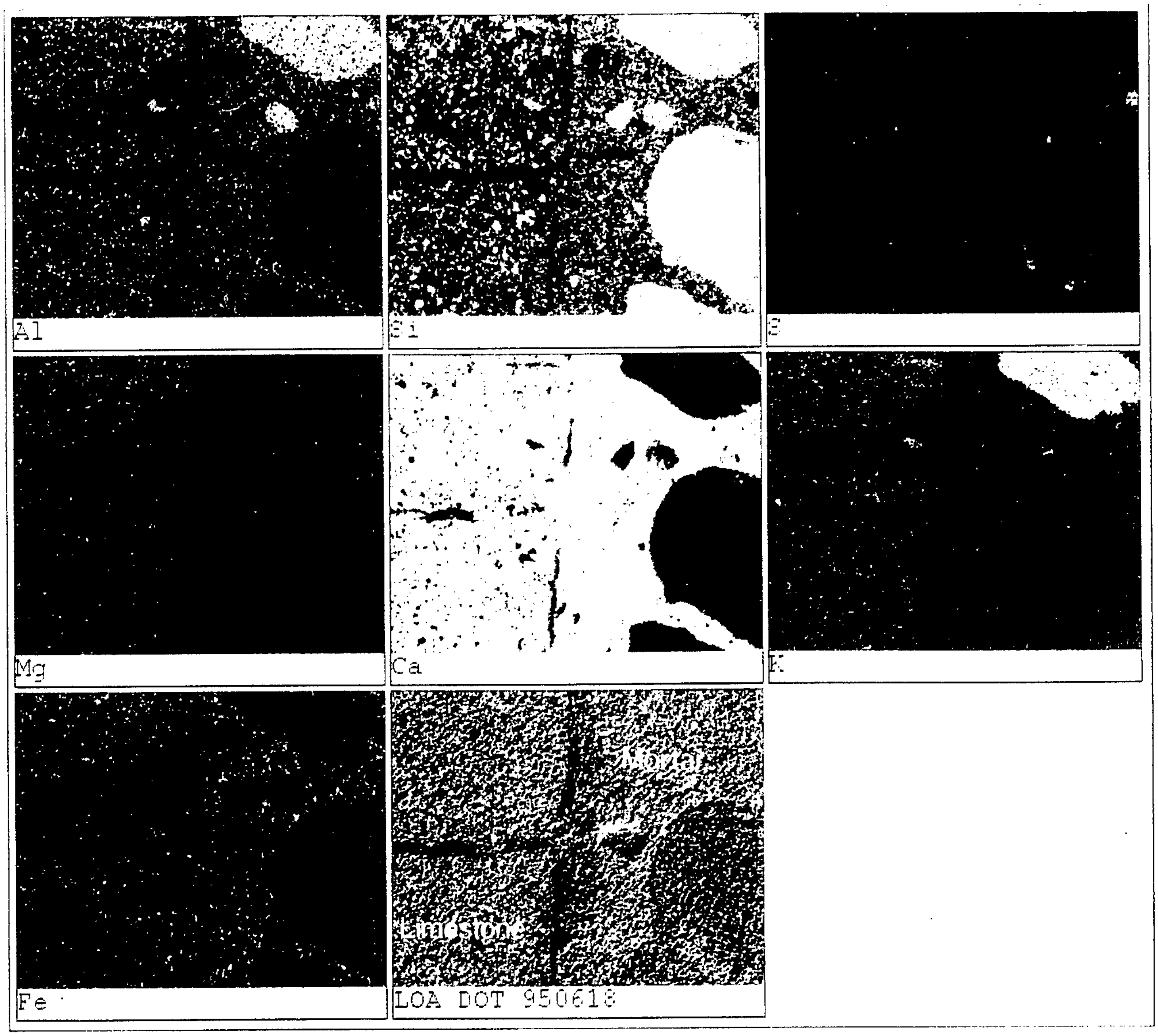


Figure 27. High-resolution X-ray elemental map of reactive coarse aggregate interface with paste. No migration of elements is observed

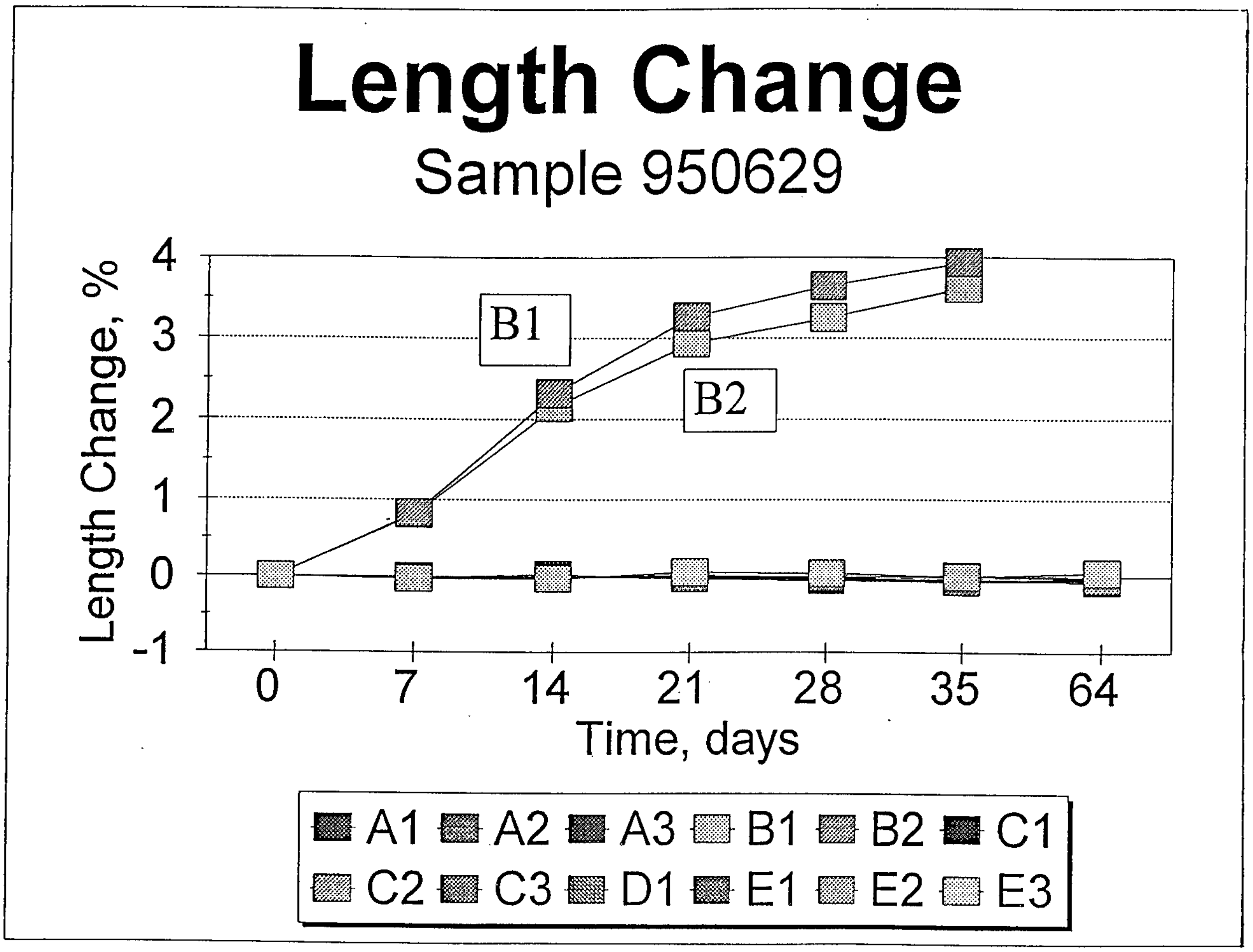


Figure 28. Rock cylinder test shows two specimens (B1 and B2) from sample 950629 expanding quickly while others did not expand. Cores were taken from five particles (A, B, C, D, and E) representing varieties of rock

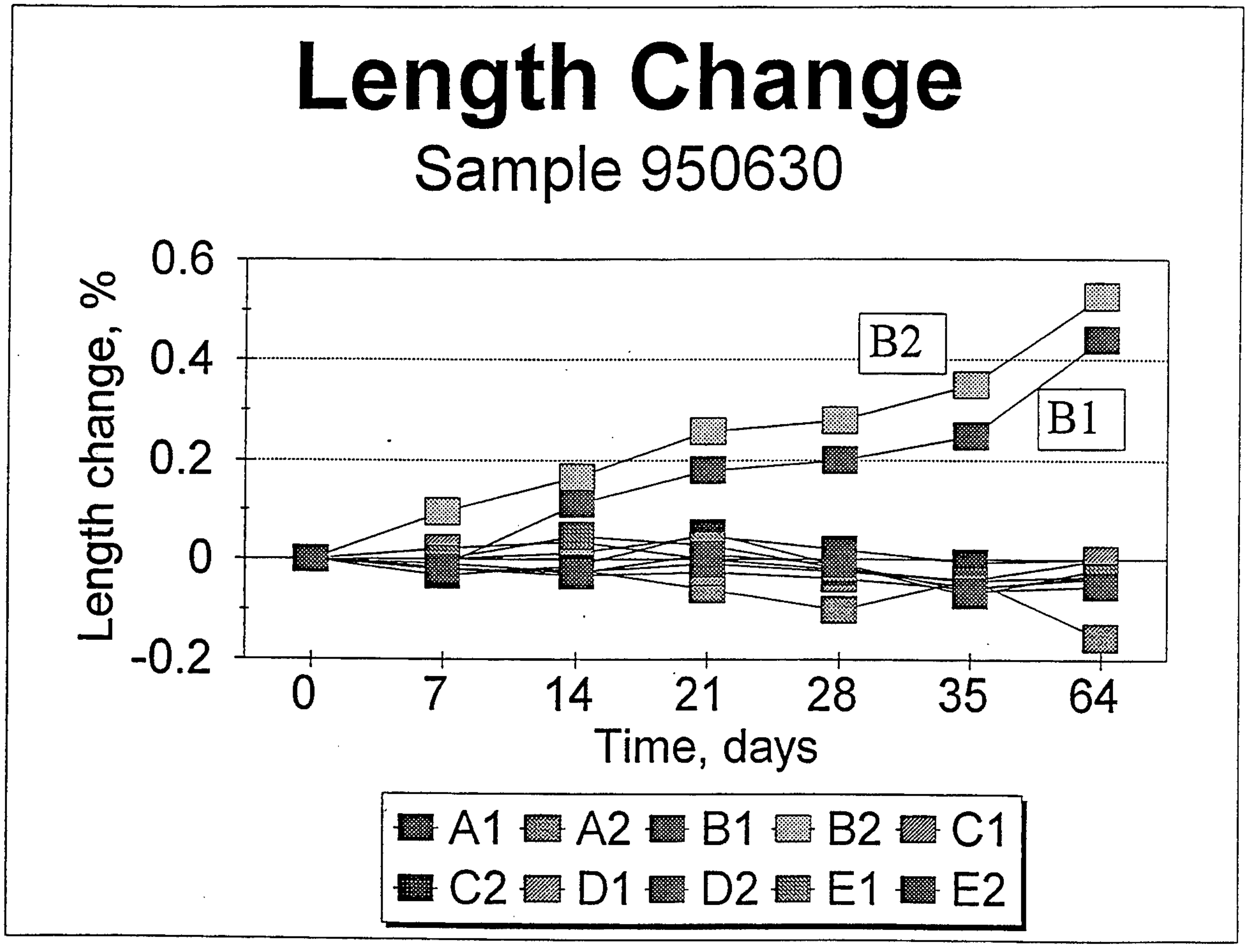


Figure 29. Rock cylinder test shows two specimens (B1 and B2) from sample 950630 expanding while others did not expand. Cores were taken from five particles (A, B, C, D, and E) representing varieties of rock

Table 1
Information of I-20 Cores and Aggregate Samples Near Monroe, LA

Item	CTD Serial No.	DOTD Core No.	Location	Degree of Cracking
Westbound land west of Monroe, showing little distress; log miles begin at Lincoln PL westward				
1	950623	1	Log mile 1.5, shoulder	very fine, hairline
2	950624	2	Log mile 3.1, outside land outside wheel path	hairline
Eastbound lane west of Monroe, showing major distress with cracks at joints raveling; log mile begins at LA 145 overpass eastward				
3	960625	3	Log mile 1.5, outside lane, edge	surface cracks
4	950626	4	Log mile 3.38, outside land outside wheel path	cracks near joint
5	950627	5	Log mile ?, outside lane outside wheel path	no cracks surface
6	950628	6	Log mile 4.7, outside lane outside wheel path	heavy cracking
Aggregates used in construction of I-20				
7	950629	limestone	TL James (451-05060, I-20 west of Monroe) Dravo, Smithland, KY	
8	950630	limestone	Bud Hale (451-07-29, I-20 east of Monroe), Denton Contractor, Dravo, Smithland, KY	
9	950631	sand	Denton Contractor (451-07-29 & 28)	
Eastbound lane east of Monroe, showing major distress; repairs required to prevent raveling; log mile begins at Delhi intersection mile post 153				
10	950620	7	Log mile 1.58 outside lane outside wheel path	cracking
11	950619	8	Log mile 1.7 outside lane outside wheel path	cracking
12	960617	9	Log mile 1.79 outside land outside wheel path	heavy cracking
13	950614	10	Log mile 1.79 shoulder	cracked
14	950616	11	Log mile 2.38 outside lane	light cracking
15	950622	12	Log mile 2.38 shoulder	no cracks
16	950618	13	Log mile 3.7 edge	heavy cracking
Westbound lane east of Monroe showing little distress; log mile begins at mile post 157 westward				
17	950621	14	Log mile 0.10 outside lane outside wheel path	very light crack
18	950615	15	Log mile 0.10 shoulder	no crack

Table 2
Evaluation Matrix

Item	CTD Serial No.	DOTD Core No.	Pulse Velocity	Petrographic Examination	X-ray Diffraction	Expansion	Cement Content
1	950623	1	✔	✔	✔		✔
2	950624	2	✔				
3	950625	3		✔		✔	
4	950626	4	✔	✔		✔	✔
5	950627	5	✔	✔			
6	950628	6	✔	✔	✔		
7	950629	limestone		✔			
8	950630	limestone		✔			
9	950631	sand					
10	950620	7	✔	✔	✔		
11	950619	8	✔	✔			
12	950617	9		✔			✔
13	950614	10	✔				
14	950616	11	✔	✔	✔		
15	950622	12	✔	✔			
16	950621	13		✔			
17	950621	14	✔	✔	✔		✔
18	950615	15	✔	✔			

Table 3
Pulse Velocity Data

Specimen ID	Length, in. (mm)	Diameter, in. (mm)	Time, μsec	Velocity, ft/sec (N)
950623	10.625 (270)	6 (152)	59.0	15,000 (66,723)
950626[1]	12.000 (305)	6 (152)	94.3	10,600 (47,151)
950627	12.063 (306)	6 (152)	69.1	14,550 (64,721)
950628[1]	12.313 (313)	6 (152)	135.7	7,560 (33,629)
950620	10.875 (276)	6 (152)	77.8	11,650 (51,821)
950614	10.625 (270)	6 (152)	73.7	12,010 (53,423)
950619	10.625 (270)	6 (152)	74.6	11,870 (52,800)
950616	10.625 (270)	6 (152)	67.4	13,140 (58,800)
950622	9.688 (246)	6 (152)	53.8	15,040 (66,901)
950621	10.938 (278)	6 (152)	58.9	15,470 (68,814)
950615	9.625 (244)	6 (152)	53.0	15,130 (67,302)

[1] Specimens were cracked.

Table 4
Result of Cement-Content Analysis

Property	Sample No.			
	950623	950626	950617	950621
Combined Water, %	2.32	1.69	2.36	2.25
Insoluble Residue, %	86.20	87.41	86.33	81.53
Free Water, %	4.67	4.13	5.28	3.62
Density, lb/ft^3	148.6 (2,380)	149.2 (2,390)	148.6 (2,380)	145.5 (2,331)
Cement Content, lb/yd^3	438 (260)	420 (249)	430 (255)	613 (364)

Appendix A
Photographs of Concrete Sections

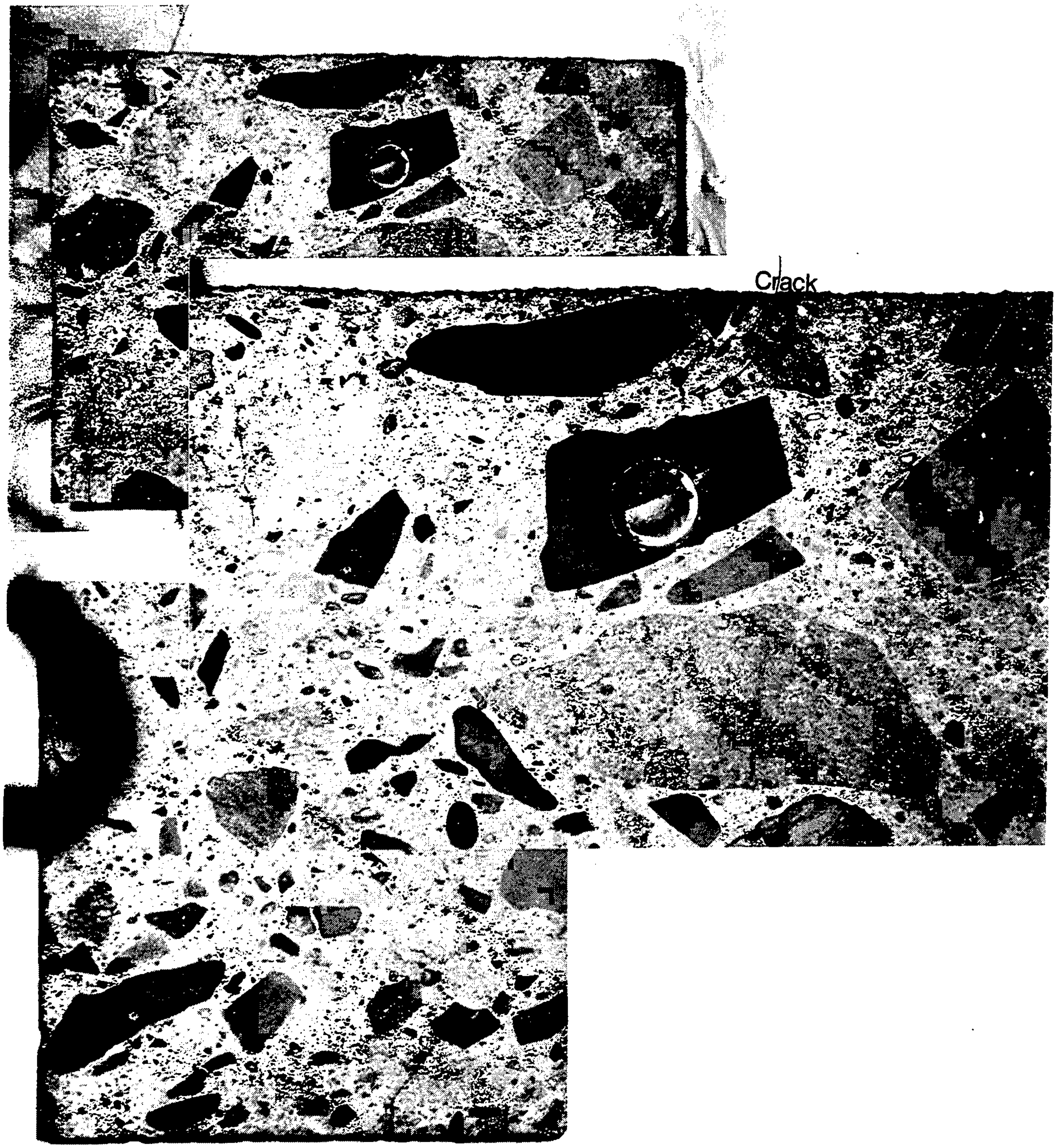


Figure A1. Sample 950623 shows reactive particles 1 and 2 near top surface associated with cracks. The top and bottom samples are 6 in. (152 mm) left to right

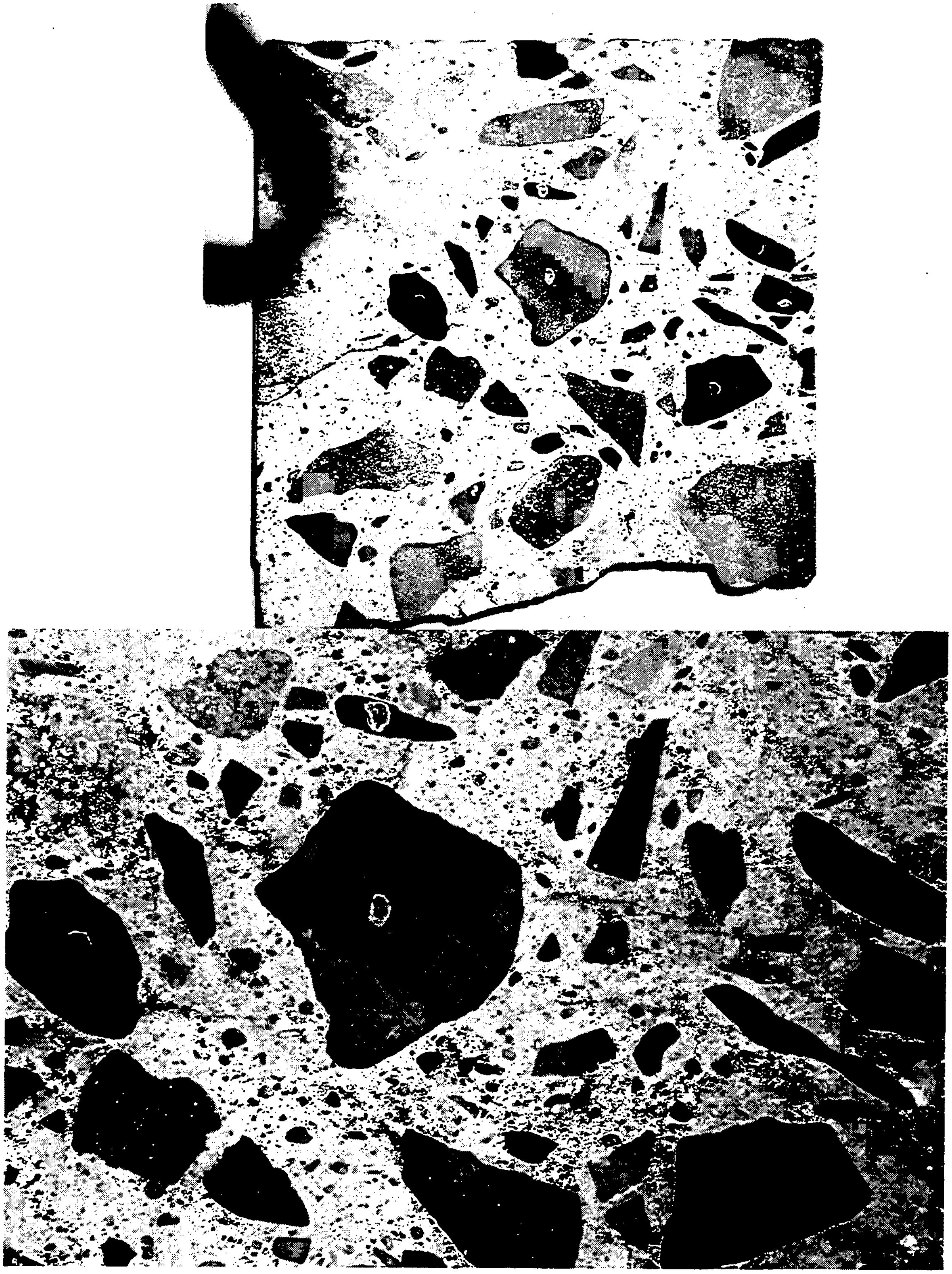


Figure A2. Sample 950623 shows a random crack pattern with cracks propagating from central reactive coarse aggregate. Other reactive aggregate particles are also present. Top sample is 6 in. (152 mm) left to right

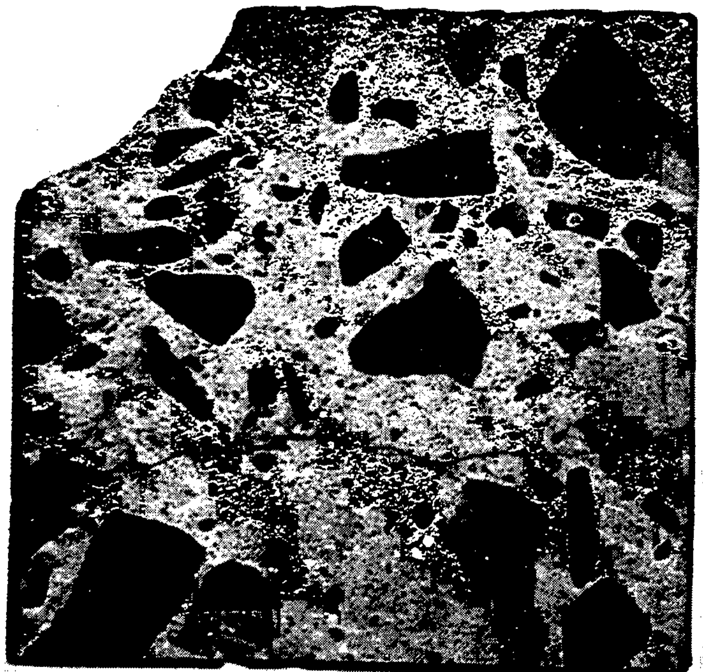


Figure A3a. Sample 950626 shows some interior cracking in the concrete and a few small reactive particles with reaction rims. The sample is 6 in. (152 mm) left to right

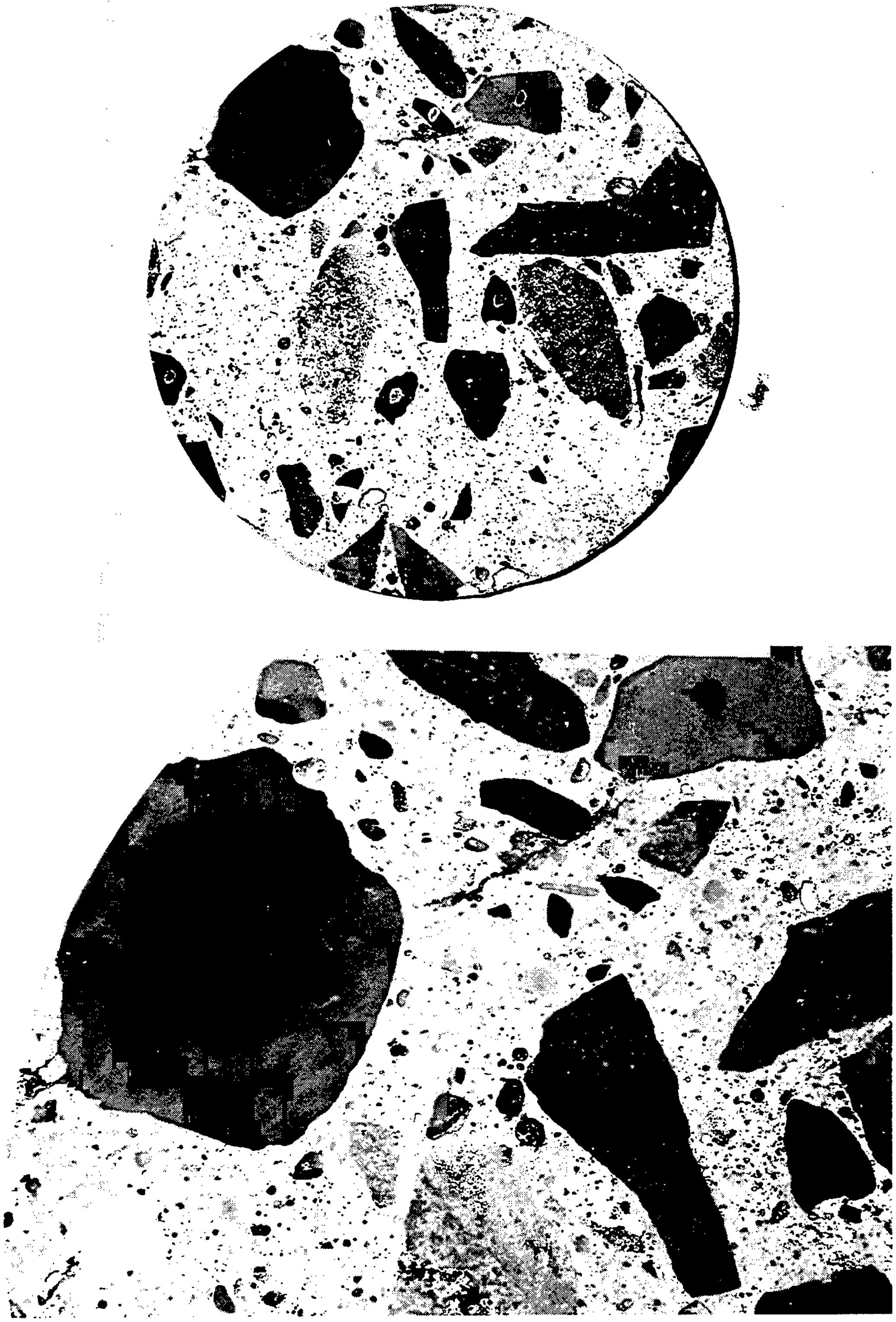


Figure A3b. Sample 950626 shows reactive aggregate particles at bottom of core. The sample is 6 in. (152 mm) left to right

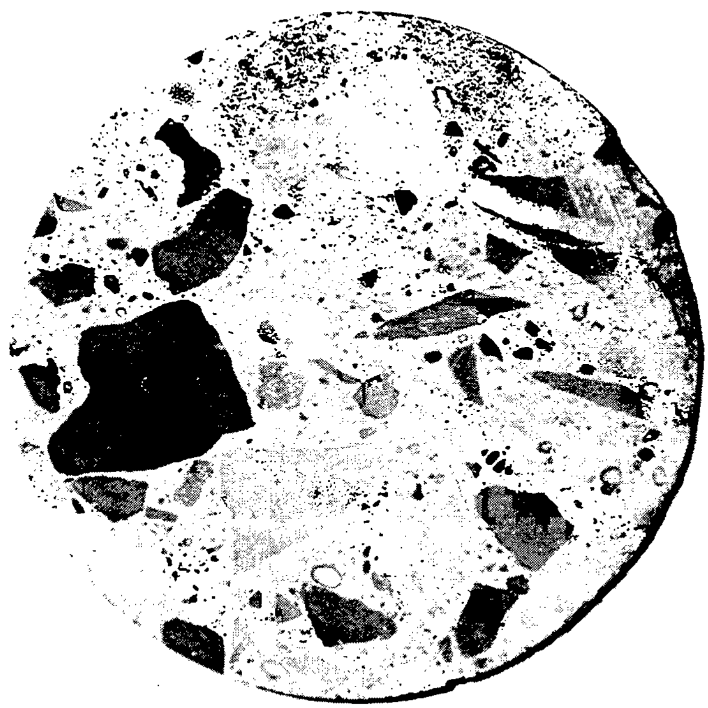


Figure A4. Sample 950627 shows no cracks. The sample is 6 in. (152 mm) left to right

Figure A5a. Sample 950628 shows severe cracking in near surface concrete. Epoxy resin fills the cracks. Top sample is 6 in. (152 mm) left to right

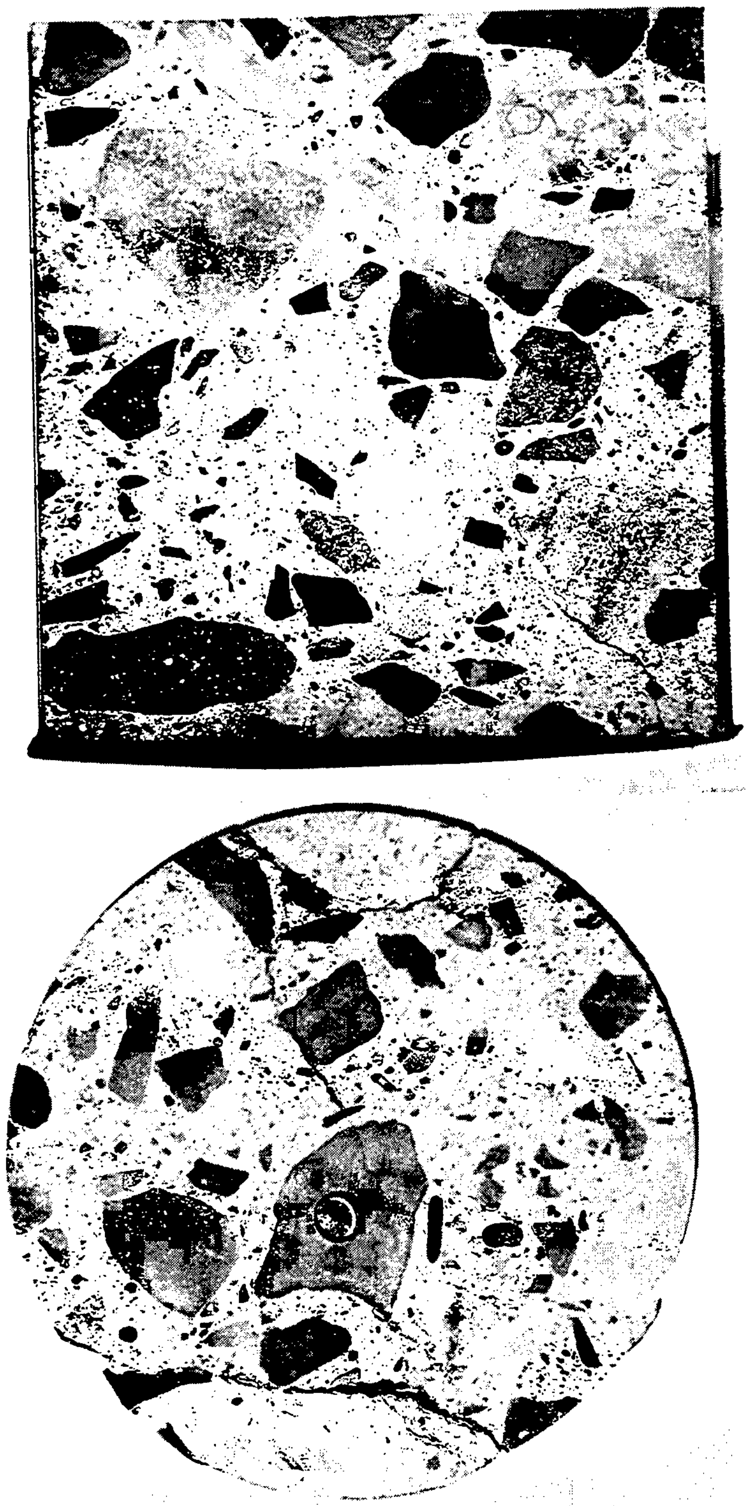


Figure A5b. Sample 950628 shows cracking is continuous throughout the entire length of core. Both samples are 6 in. (152 mm) left to right

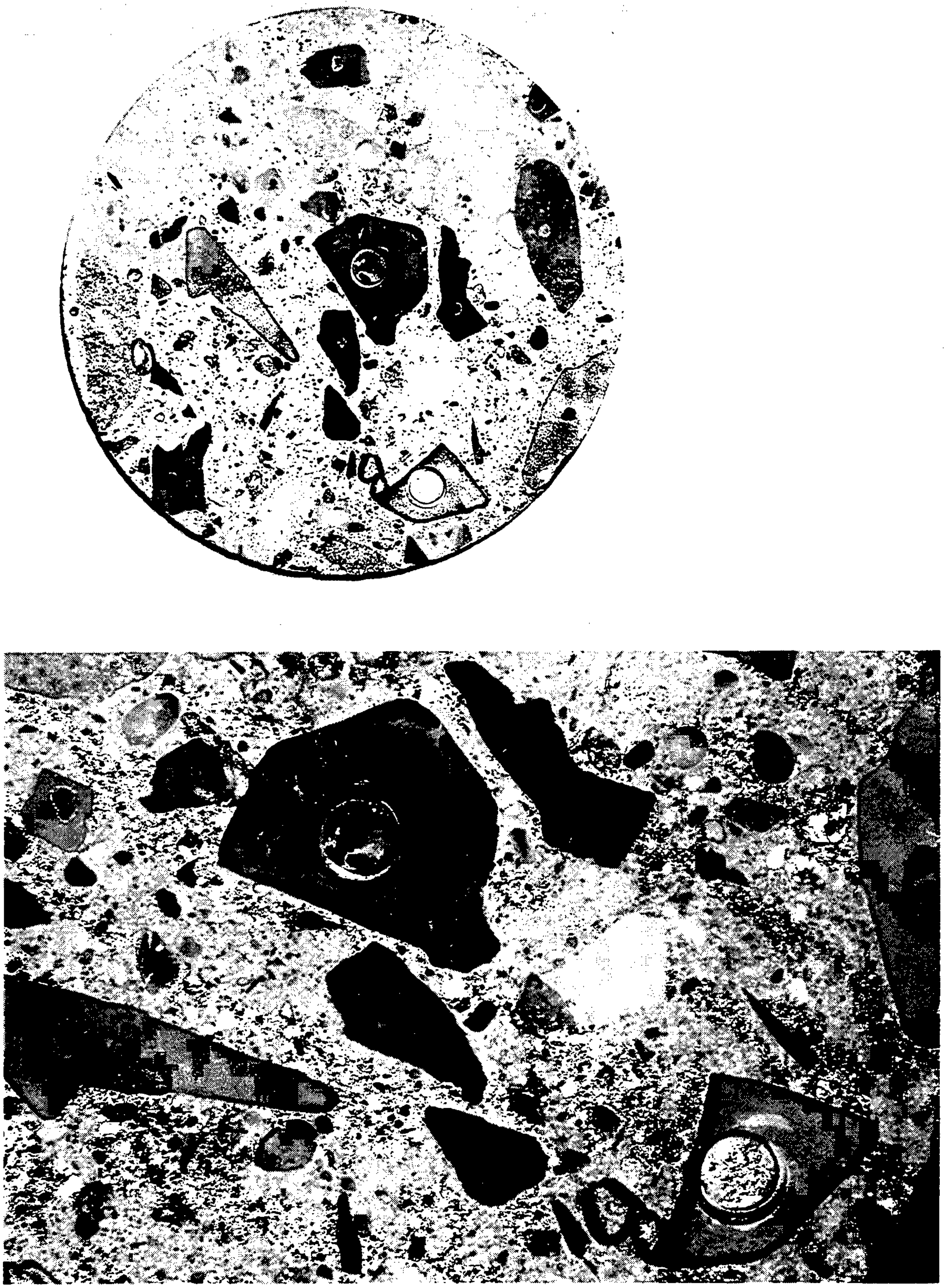


Figure A6. Sample 950620 shows aggregate reaction at the base of the core. Cracks are visible along the reaction rim. Top sample is 6 in. (152 mm) left to right

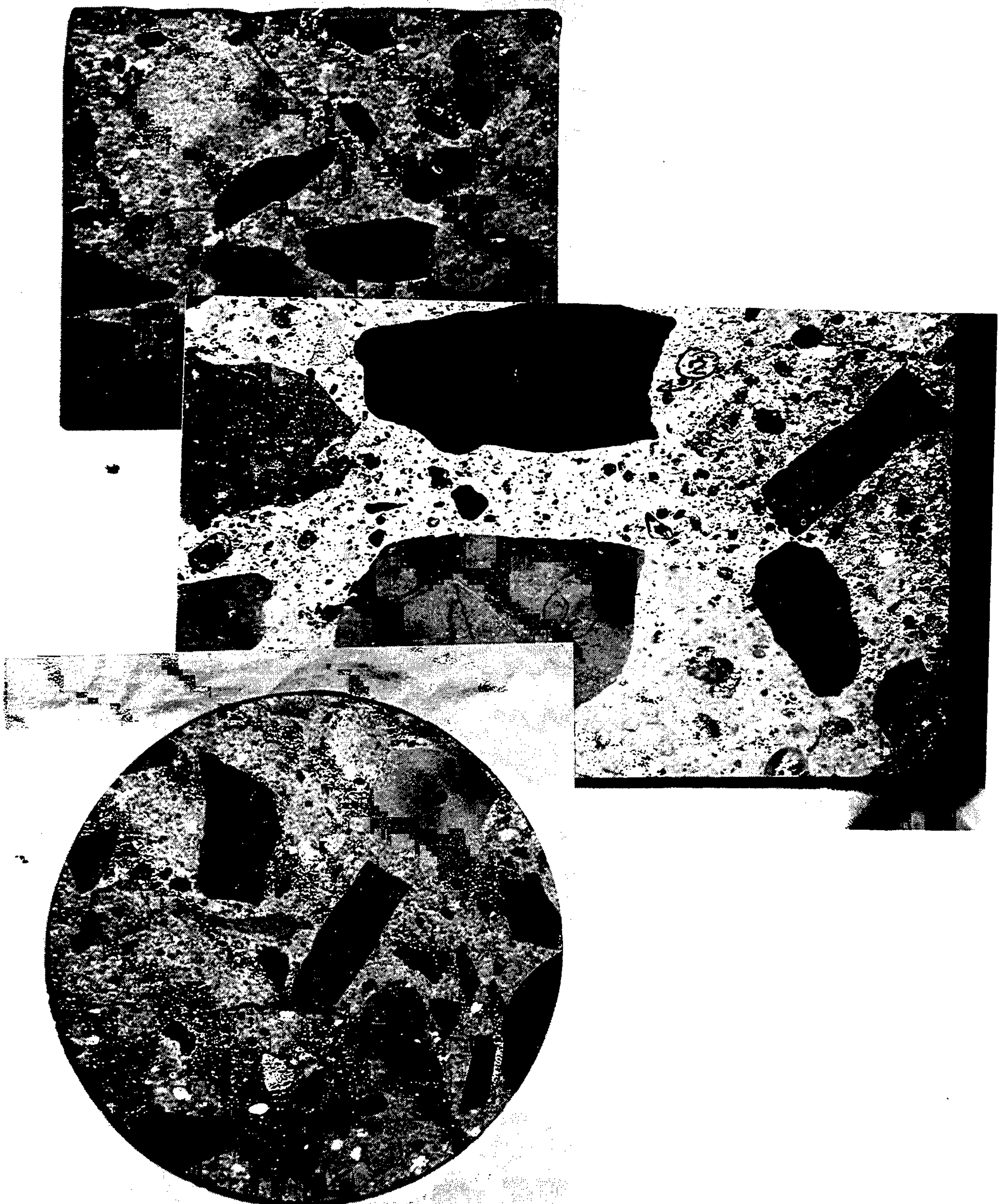


Figure A7. Sample 950619 shows random crack pattern with cracks propagating from two central reactive coarse-aggregate particles and cracking in bottom end of sample. Top and bottom samples are 6 in. (152 mm) left to right

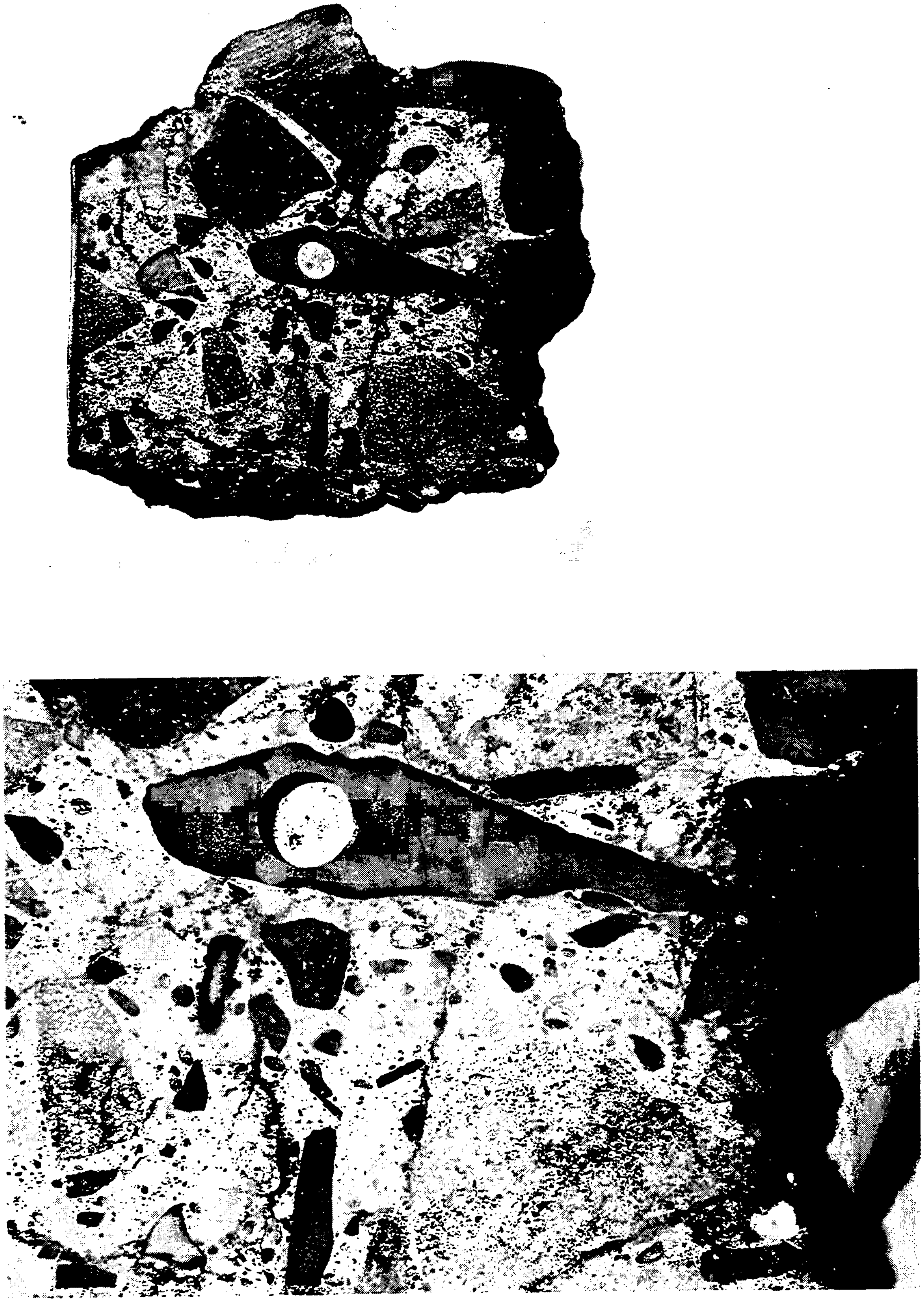


Figure A8. Sample 950617 shows a reactive aggregate particle and cracking of rim zone. Diameter core boring is 11 mm

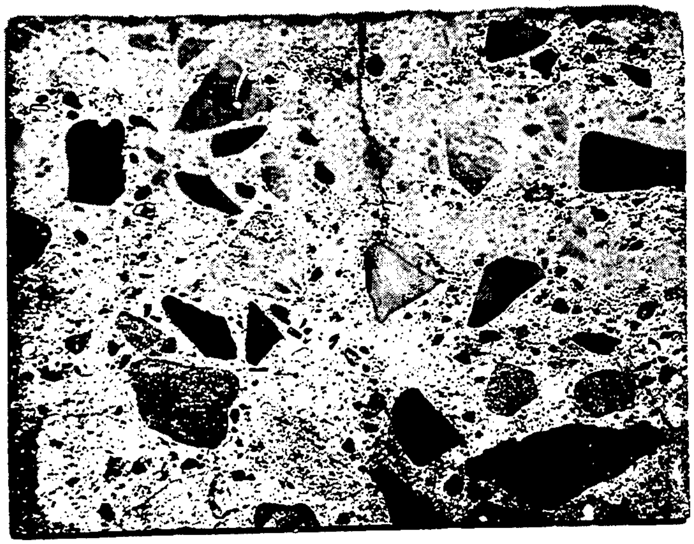


Figure A9a. Sample 950616 shows a central vertical near-surface crack and some incipient cracks associated with aggregate particle A. Samples on left are 6 in. (152 mm) left to right

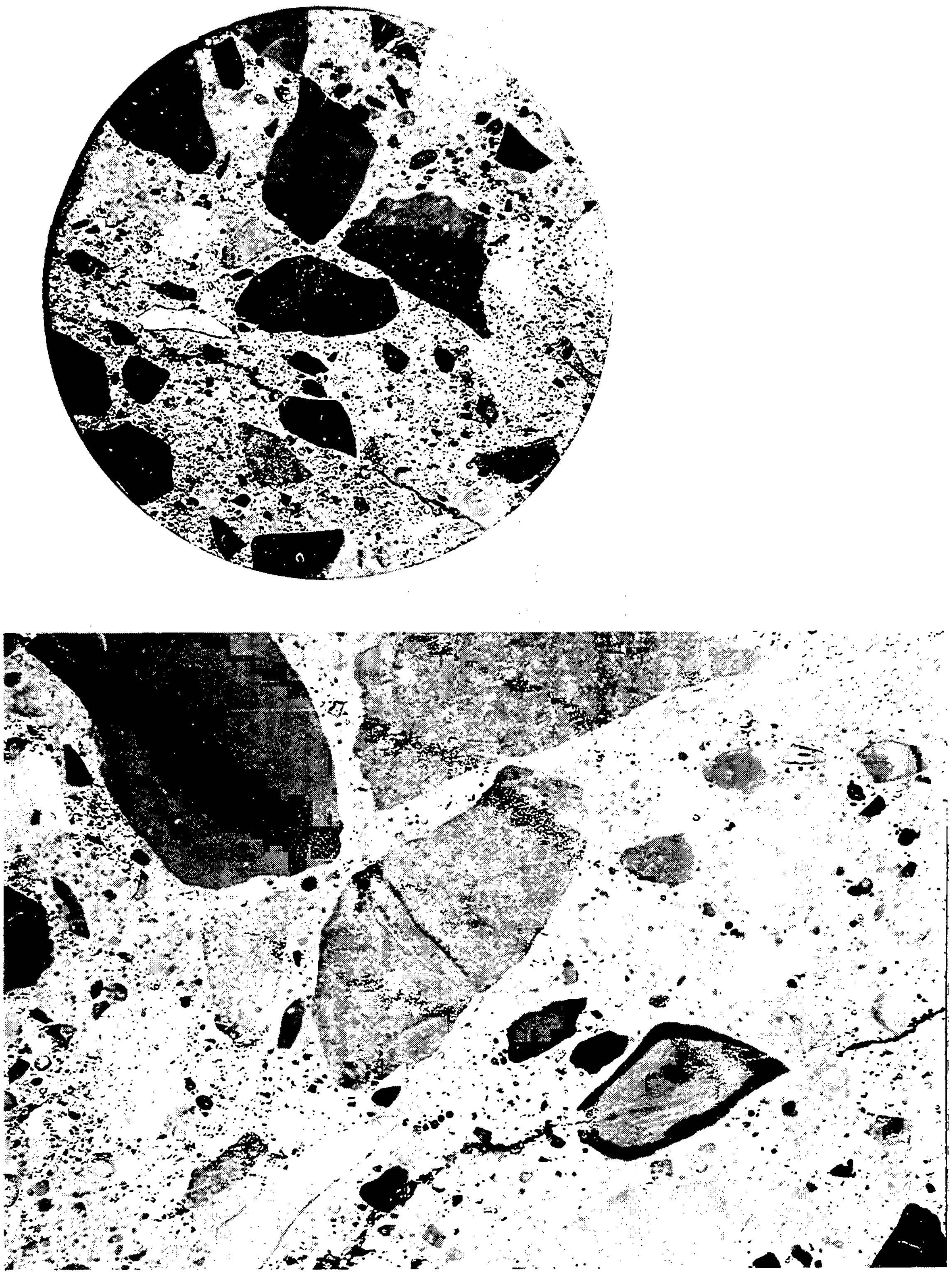
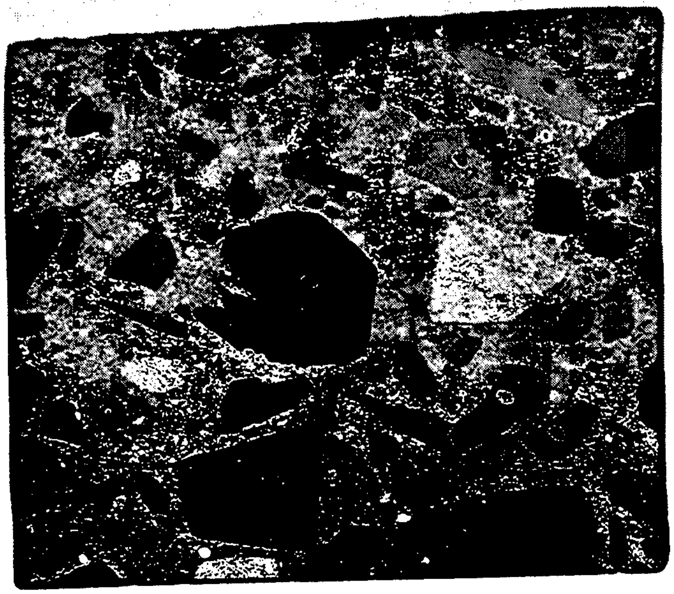


Figure A9b. Sample 950616 shows bottom of core and crack associated with reactive aggregate particle. Top sample is 6 in. (152 mm) left to right

Figure A10. Sample 950622 shows intact concrete with mostly light-colored aggregate particles. Bottom slice of core contains hairline crack. Both samples are 6 in. (152 mm) left to right



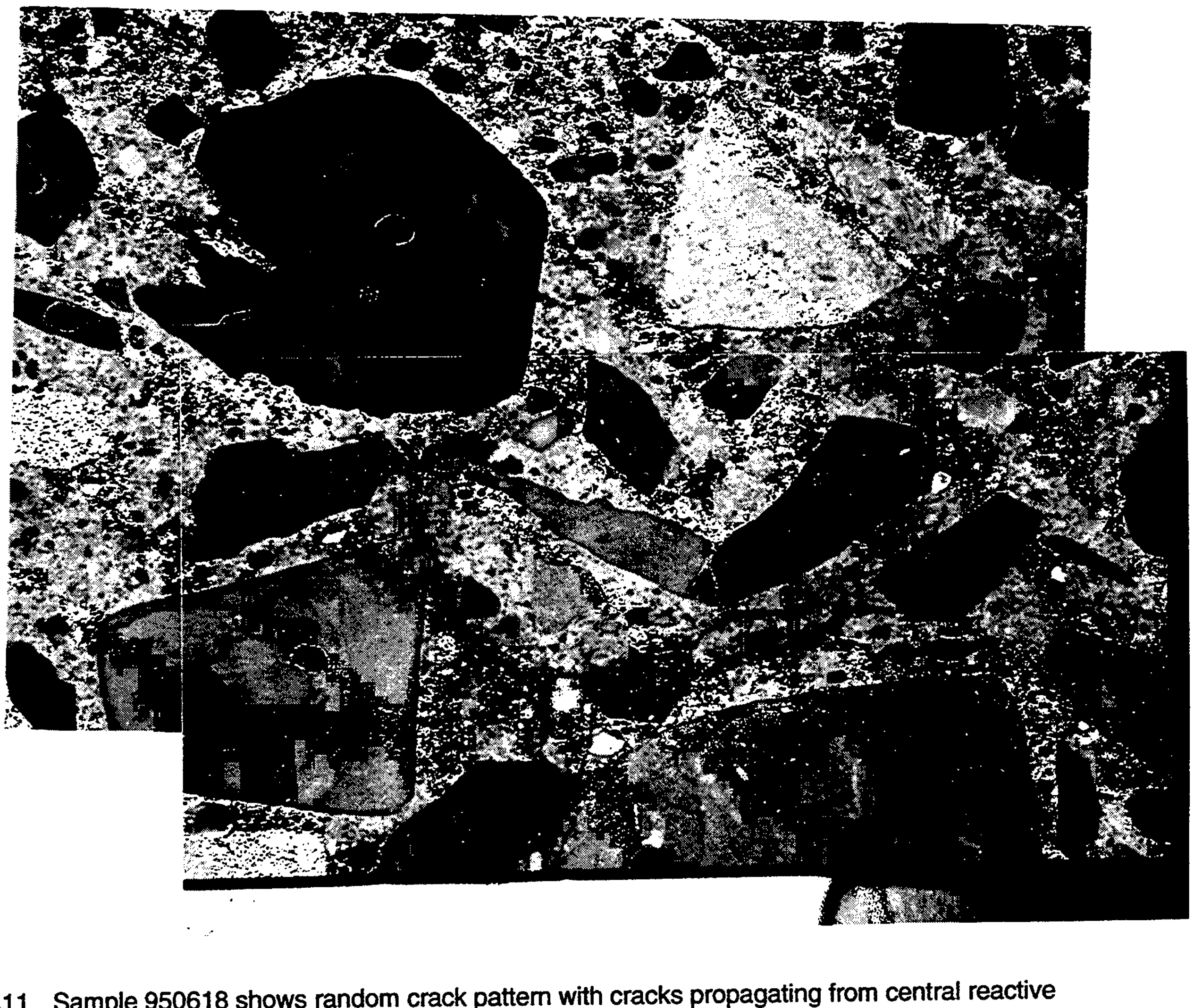


Figure A11. Sample 950618 shows random crack pattern with cracks propagating from central reactive coarse-aggregate particle. Other reactive particles are also evident. Top sample is 6 in. (152 mm) left to right

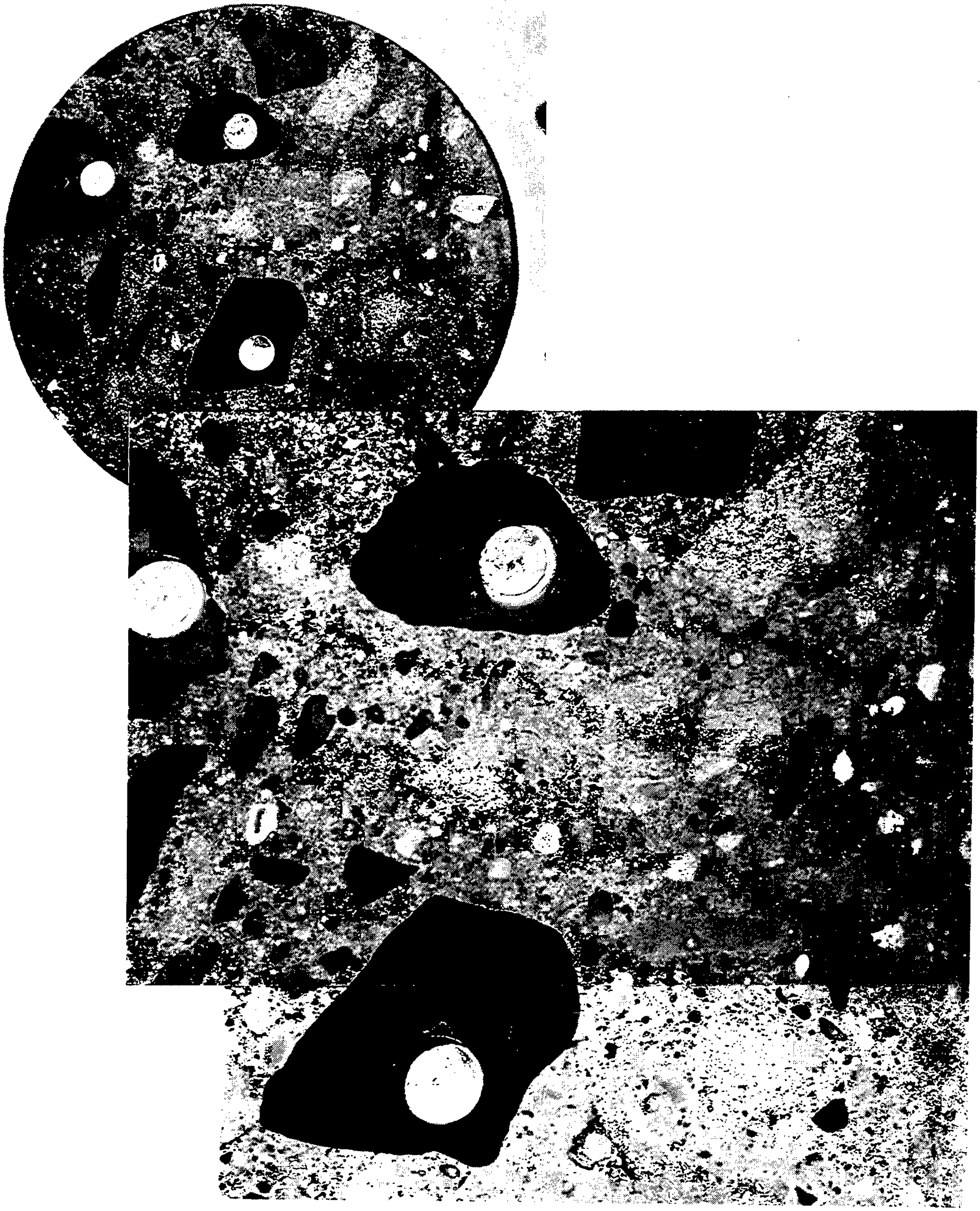


Figure A12. Sample 960621 shows aggregate particles A, B, and C. A is non-expansive, B is non-expansive, and C is expansive. Top sample is 6 in. (152 mm) left to right

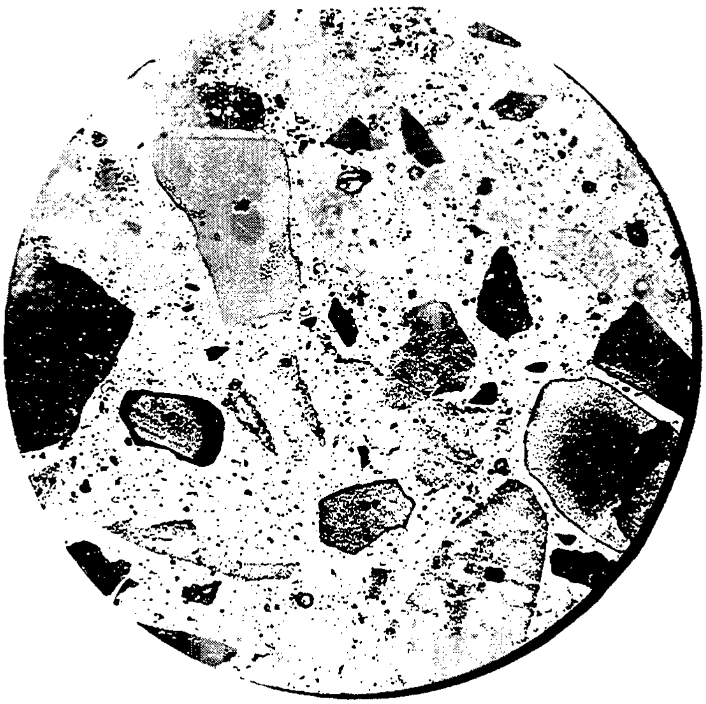


Figure A13. Sample 950615 shows some non-expansive reactive aggregate particles. Top sample is 6 in. (152 mm) left to right

Appendix B
U.S. Army Corps of Engineers Evaluation Data

Issued Sept 1971

AGGREGATE DATA SHEET

STATE Ky.	INDEX NO 29	AGGREGATE DATA SHEET	TESTED BY: ORD Lab.
LAT. 37°	LONG. 88°		DATE November 1970

LAB. SYMBOL NO 7196-71100 TYPE OF MATERIAL: Crushed Limestone

LOCATION Smithland

PRODUCER Three Rivers Rock Co.

SAMPLED BY Nashville District C. of E. Personnel

TESTED FOR Smithland L&D

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE

GRADING (CRD-C 103) (CUM. % PASSING)

SIEVE	3-6"	1½-3"	¾-1½"	#4-¾"	FINE AGG.
6 IN					
5 IN	84.6				
4 IN	41.5				
3 IN	4.6	51.4			
2½ IN					
2 IN		12.5			
1½ IN		1.4			
1 IN			58.1		
¾ IN			14.2		
½ IN			4.2	69.8	
⅜ IN			2.7	40.8	
NO. 4			1.3	14.8	
NO. 8					82.6
NO. 16					71.6
NO. 30					46.4
NO. 50					29.5
NO. 100					17.9
NO. 200					
-200[a]					
F.M.[b]					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS

	3-6"	1½-3"	¾-1½" (c)	#4-¾" (c)	FINE AGG.
BULK SP. GR., SAT SURF DRY (CRD-C 107,108):	2.66	2.70	2.67	2.72	2.61
ABSORPTION, PER CENT (CRD-C 107, 108):	0.80	0.77	1.22	0.28	1.99
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121):	—	—	—	—	
SOFT PARTICLES, PER CENT (CRD-C 130):					—
PER CENT LIGHTER THAN SP. GR. ___ (CRD-C 129):					—
PER CENT FLAT AND ELONGATED (CRD-C 119,120):					
WEIGHTED AV. % LOSS, 5 CYC. $MgSO_4$ (c) ¾-1", #4-¾) (CRD-C 115)	3.03				26.9
ABRASION LOSS (L. A.), %, (CRD-C 117): B				21.5	—
UNIT WT., LB/CU FT (CRD-C 106):					
CLAY LUMPS, % (CRD-C 118)					
COAL AND LIGNITE, % (CRD-C 122):	—	—	—	—	
SPECIFIC HEAT, BTU/LB/DEG. F. (CRD-C 124):					
REACTIVITY WITH NaOH (CRD-C 128): Sc, mM/L					
Rc, mM/L					

MORTAR-MAKING PROPERTIES (CRD-C 116)

TYPE ____ CEMENT, RATIO ____ DAYS, ____ %, ____ DAYS, ____ %

LINEAR THERMAL EXPANSION X10⁻⁶/DEG. F. (CRD-C 125,126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):	FINE AGGREGATE 3 MO.	6 MO.	9 MO.	12 MO.	COARSE AGGREGATE 3 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT: % Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT: % Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):			F & T	HW-CD	HD-CW
FINE AGG Newtown	COARSE AGG: Three Rivers	DFE_{300}	79.0		
FINE AGG. Three Rivers	COARSE AGG: Melvin	DFE_{300}	81.9		

PETROGRAPHIC DATA (CRD-C 127):

Sample consist of varying amounts of dense, hard, particles of Oolitic Limestone, Fossiliferous Limestone, and Dolomitic Limestone. About 1% to 2% of each sample consists of moderately hard to moderately soft, moderately tough Argillaceous Dolomitic Limestone. A trace amount of the 3" max. size aggregate consists of potentially reactive Chert.

REMARKS:

WES FORM 726 JAN 1951

Issued Sept 1975

AGGREGATE DATA SHEET

STATE Ky.	INDEX NO 29 (supp)	TESTED BY ORDED-FL	
LAT 37°	LONG 88°	DATE	
LAB SYMBOL NO 75071		TYPE OF MATERIAL Crushed Coarse Aggregate (1½"-3")	

LOCATION: Smithland, Ky.

PRODUCER: Three Rivers Quarry

SAMPLED BY: Nashville District CofE personnel

TESTED FOR: Elementary Acceptance Tests for Smithland Locks & Dam Proj.

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

GRADING (CRD-C 103) (CUM % PASSING)

SIEVE	3-6"	1½-3	¾-1½"	#4-¾	FINE AGG
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.					
1 IN.					
¾ IN.					
½ IN.					
⅜ IN.					
NO. 4					
NO. 8					
NO. 16					
NO. 30					
NO. 50					
NO. 100					
NO. 200					
-200 (a)					
F.M. (b)					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS

TEST	3-6"	1½-3	¾-1½"	#4-¾"	FINE AGG
BULK SP. GR. S.S.D. (CRD-C 107, 108)				2.62	
ABSORPTION, % (CRD-C 107, 108)				2.33	
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	—	—	
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR 2.0 (CRD-C 122)				-0-	
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)				16.4*	
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING A				35.7	
UNIT WT, LB/CU FT (CRD-C 106)					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU LB/DEG F. (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128) SC, MM/L					
REACTIVITY WITH NaOH (CRD-C 128) RC, MM/L					

MORTAR-MAKING PROPERTIES (CRD-C 116)

TYPE ____ CEMENT, RATIO ____ DAYS ____ DAYS ____

LINEAR THERMAL EXPANSION MILLIONTHS/DEG F. (CRD-C 125, 126)

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123)	FINE AGGREGATE 2 MO.	6 MO	9 MO.	12 MO.	COARSE AGGREGATE 3 MO.	6 MO	9 MO.	12 MO
LOW-ALK. CEMENT % Na_2O EQUIVALENT								
HIGH-ALK. CEMENT % Na_2O EQUIVALENT								

SOUNDNESS IN CONCRETE (CRD-C 40, 114)

			F&T	HW-CD	HD-CW
FINE AGG. Lab. Std.	COARSE AGG 3 Rivers Quarry (#4-3/4")	DFE 300	73%		
FINE AGG.	COARSE AGG	DFE 300			

PETROGRAPHIC DATA (CRD-C 127)

Material consists of a composite of stone from Ledges 7A, 7B, and 7C of this quarry.

REMARKS

*$MgSo_4$ grading as per CRD C-3 100% passing 1½" agg.

ENG FORM 6011-R 1 MAR 1964

1988

STATE: KY	INDEX NO.: 29 Suppl 5	AGGREGATE DATA SHEET	TESTED BY: USAE WES
LAT.: 37	LONG.: 88		DATE: March, 1986

LAB SYMBOL NO.: VICKS-33 MG-8 TYPE OF MATERIAL: Manufactured Gravel

LOCATION: 7 miles NE of Smithland, KY, on Hwy 60

PRODUCER: Three Rivers Rock Co., Smithland, KY

SAMPLED BY: Vicksburg District

TESTED FOR: Yazoo Backwater Pumping Plant

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

GRADING (CRD-C 103) (CUM. % PASSING):

SIEVE	3-6"	1½-3"	¾-1½"	#4-¾"	FINE AGG.
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.			100		
1 IN.			22		
¾ IN.			2		
½ IN.			1		
⅜ IN.			1		
NO. 4			1		
NO. 8					
NO. 16					
NO. 30					
NO. 50					
NO. 100					
NO. 200					
-200(a)					
F.M.(b)					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS

	3-6"	1½-3"	¾-1½"	#4-¾"	FINE AGG.
BULK SP GR, S.S.D. (CRD-C 107, 108)			2.68		
ABSORPTION, % (CRD-C 107, 108):			0.9		
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	—	—	
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING A			25.2		
UNIT WT, LB/CU FT (CRD-C 106):			167.2		
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F, (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128): Sc, MM/L:					
Rc, MM/L:					

MORTAR-MAKING PROPERTIES (CRD-C 116)

TYPE ____ CEMENT, RATIO: ____ DAYS, ____ %, ____ DAYS, ____ %

LINEAR THERMAL EXPANSION, MILLIONTHS/DEG F, (CRD-C 125, 126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):		FINE AGGREGATE 2 MO.	6 MO.	9 MO.	12 MO.	COARSE AGGREGATE 3 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT:	% Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT:	% Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):			F&T	HW-CD	HD-CW
FINE AGG.	COARSE AGG:	DFE_{300}			
FINE AGG.	COARSE AGG:	DFE_{300}			

PETROGRAPHIC DATA (CRD-C 127):

Fossiliferous dolomitic limestone comprised the crushed stone sample from Three Rivers Rock Co.'s Smithland Quarry. Over 60 percent is medium gray and fine to coarse crystalline. Approximately 30 percent of the particles are dark gray and fine to coarse crystalline. Of the latter group, 12 percent are considered undesirable by the writer because of their highlv argillaceous nature (approximately 20 percent). About 1 percent of the sample is weathered and of very poor quality. It is suggested that the quarry be investigated to determine if selective quarrying is feasible to eliminate the dark gray highly argillaceous rocks.

REMARKS:

ENG FORM 1 MAR 1966 6011-R

Encl 17 to Encl 1

1988

STATE: KY	INDEX NO.: 29 Suppl 3	RIPRAP DATA SHEET	TESTED BY: SAD Laboratory
LAT.: 37	LONG.: 88		DATE: 14 July 1986

LAB SYMBOL NO.: 57/3013 TYPE OF MATERIAL:

LOCATION: 5.2 miles E. of Smithland KY on US 60

PRODUCER: Three Rivers Rock Quarry

SAMPLED BY: Sanders (CESAM-EN-FG)

TESTED FOR: Oliver L&D Replacement

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE.

TEST METHOD	RESULTS
BULK SPECIFIC GRAVITY, SSD, (CRD-C 107)	
ABSORPTION, % (CRD-C 107)	
WT. AV. % LOSS, 5 CYC. $MGSO_4$ (CRD-C 137)	
L.A. ABRASION LOSS, % (CRD C 145 OR RTH-115), GRADING 1.	
UNIT WT., LB/CU FT (CRD-C 107)	
WETTING AND DRYING, %, 35 CYCLES	
FREEZE AND THAW, % (CRD-C 144) 20 CYCLES Avg. of 11 pieces	1.5
EXPANSION IN ETHYLENE, GLYCOL (CRD-C 148)	

PETROGRAPHIC DATA (CRD-C 127)

REMARKS

ENG FORM 6012-R, Jul 81 (ER 1110-1-2005) (Proponent DAEN-CWE-DC)

1988

STATE: KY	INDEX NO.: 29 Suppl 4	**RIPRAP DATA SHEET**	TESTED BY: USAEWES
LAT.: 37	LONG.: 88		DATE: March 1986

LAB SYMBOL NO.: VICKS 33 RR-8 TYPE OF MATERIAL: Limestone

LOCATION: 7 miles NE of Smithland, KY on Hwy 60

PRODUCER: Three Rivers Rock Co., Smithland, KY

SAMPLED BY: Vicksburg District

TESTED FOR: Yazoo Backwater Pumping Plant

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

TEST METHOD	RESULTS
BULK SPECIFIC GRAVITY, SSD, (CRD-C 107)	2.73
ABSORPTION, % (CRD-C 107)	0
WT. AV. % LOSS, 5 CYC. $MGSO_4$ (CRD-C 137)	
L.A. ABRASION LOSS, % (CRD-C 145 OR RTH-115), GRADING 1.	27.0
UNIT WT., LB/CU FT (CRD-C 107)	170.1
WETTING AND DRYING, %, 35 CYCLES	0.7
FREEZE AND THAW, % (CRD-C 144) 20 CYCLES	20.7
EXPANSION IN ETHYLENE, GLYCOL (CRD-C 148)	

PETROGRAPHIC DATA (CRD-C 127)

This rock was a light olive gray, fine-grained limestone. The rock is slightly fossiliferous, with bedding planes 0.01 ft apart. The rock is composed of calcite, dolomite, quartz, and kaolinite. This rock should perform adequately for use as riprap.

REMARKS

ENG FORM 6012-R, Jul 81 (ER 1110-1-2005) (Proponent DAEN-CWE-DC)

Encl 26 to Encl 1

Issued October 1982

STATE: KY	INDEX NO.: 29 (Suppl 2)	RIPRAP DATA SHEET	TESTED BY: USAEWES
LAT.: 37	LONG.: 88		DATE: March 1979

LAB SYMBOL NO.: NO-57 G-136 TYPE OF MATERIAL: Riprap

LOCATION: 1 mile east of Hwy 60 and 4.8 miles north of intersection of Hwys 60 and 70

PRODUCER: Three Rivers Rock Co., Box 218, Smithland, KY 42081

SAMPLED BY: Dames & Moore

TESTED FOR: New Orleans District

USED AT:

PROCESSING BEFORE TESTING: As required for testing

GEOLOGICAL FORMATION AND AGE: Ste. Genevieve Fm. - Meramec Group - Mississippian Age

TEST RESULTS

TEST METHOD	RESULTS
Bulk Specific Gravity, SSD, (CRD-C 107)	2.69
Absorption, % (CRD-C 107)	0.3
Wt. Av. % Loss, 5 Cyc. $MgSO_4$ (CRD-C 137)	0.0
L.A. Abrasion Loss, % (CRD-C 145 or RTH-115), Grading 1.	22.8
Unit Wt., lb/cu ft (CRD-C 107)	167.6
Wetting and Drying, %, 35 cycles	6.1
Freeze and Thaw, % (CRD-C 144) 20 cycles	0.3
Expansion in Ethylene, Glycol (CRD-C 148)	--

PETROGRAPHIC DATA (CRD-C 127)

NO-57 G-136 (Three Rivers Rock Co.). All three pieces were medium light gray coarse-grained dolomitic limestone with a minor amount of quartz; two of the three pieces were oolitic. Chert was present as layers between beds. The rock was not substantially affected by freezing and thawing.

REMARKS

New Orleans Sample No. LIV-1-1A, 1B, 1C.

1989

STATE: KY	INDEX NO.: 29 (suppl 6)	RIPRAP DATA SHEET	TESTED BY: USAEWES
LAT.: 37	LONG.: 88		DATE: Jul 88

LAB SYMBOL NO.: LMK-4 RR-16, RR-17, RR-18 TYPE OF MATERIAL: Limestone

LOCATION: Three River Quarry Bench No. 2, 3, and 4, St. Genevieve Formation Smithland, KY

PRODUCER: Dravco Basic Materials Co., Inc., Smithland, KY

SAMPLED BY: Vicksburg District

TESTED FOR: Lock and Dam No. 4 and No. 5, Red River

USED AT:

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE:

TEST METHOD	RR-17	RESULTS RR-16
BULK SPECIFIC GRAVITY, SSD, (CRD-C 107)	2.69	2.71
ABSORPTION, % (CRD-C 107)	0.6	0.7
WT. AV. % LOSS, 5 CYC. $MGSO_4$ (CRD-C 137)		
L.A. ABRASION LOSS, % (CRD-C 145 OR RTH-115), GRADING 1.		
UNIT WT., LB/CU FT (CRD-C 107)	168	169
WETTING AND DRYING, %, 35 CYCLES	0.1	0.1
FREEZE AND THAW, % (CRD-C 144) 20 CYCLES	13.7	3.9
EXPANSION IN ETHYLENE, GLYCOL (CRD-C 148)		

PETROGRAPHIC DATA (CRD-C 127)

These three samples represent benches 2, 3, and 4 of the same quarry. All three are light olive gray to medium dark gray dolomitic limestones from the St. Genevieve Formation. The rocks are very fine-grained (<0.1 mm), moderately hard to hard, slightly weathered, and massive. Samples LMK-4 RR-16 and RR-17 consist of calcite, dolomite, and quartz. Sample RR-16 contains a minor amount of plagioclase feldspar. RR-18 consists only of dolomite and quartz.

REMARKS

These rocks are similar to material previously tested. No physical tests were performed on LMK-4 RR-18; however, petrographic analyses on LMK-4 RR-16, RR-17, and RR-18 do not indicate any specific features that would preclude their use as riprap.

ENG FORM 6012-R, Jul 81 (ER 1110-1-2005) (Proponent DAEN-CWE-OC)

Issued Sept. 1973

STATE Ky.	INDEX NO. 30	AGGREGATE DATA SHEET	TESTED BY: ORDL
LAT. 37	LONG 88		DATE May 1972

LAB SYMBOL NO. 72125 & 72127 TYPE OF MATERIAL Blending Sand

LOCATION: Near Ledbetter, off US 60 on bluff overlooking Ohio River - Dubuque Ridge

PRODUCER Dravo-Groves-Newberg, Contractor

SAMPLED BY Nashville District C. of E. Personnel

TESTED FOR Smithland Locks & Dam

USED AT

PROCESSING BEFORE TESTING

GEOLOGICAL FORMATION AND AGE

GRADING (CRD-C 103) (CUM. % PASSING)

SIEVE	3-6"	1½-3	¾-1½ (72125)	#4-¾	FINE AGG. (72127)
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.					
1 IN.					
¾ IN.					
⅝ IN.					
⅜ IN.					
NO. 4					
NO. 8			99.7		98.1
NO. 16			99.6		96.5
NO. 30			99.4		94.7
NO. 50			97.9		92.1
NO. 100			70.1		54.1
NO. 200			22.2		13.8
-200 (a)					
F.M. (b)					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS	3-6"	1½-3"	¾-1½ (72125)	#4-¾"	FINE AGG. (72127)
BULK SP. GR. S.S.D. (CRD-C 107, 108)			2.53		2.54
ABSORPTION, % (CRD-C 107, 108)			1.2		1.5
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	~~1~~	—	1
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING ____					
UNIT WT, LB/CU FT (CRD-C 106)					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F. (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128): Sc, mM/L					
REACTIVITY WITH NaOH (CRD-C 128): Rc, mM/L					

MORTAR-MAKING PROPERTIES (CRD-C 116): TYPE ____ CEMENT, RATIO: ____ DAYS, ____ 7 ____ DAYS, ____

LINEAR THERMAL EXPANSION MILLIONTHS/DEG F. (CRD-C 125, 126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):	FINE AGGREGATE 2 MO.	6 MO.	9 MO.	12 MO.	COARSE AGGREGATE 3 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT: % Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT: % Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):		F&T	HW-CD	HD-CW
FINE AGG.	COARSE AGG. DFE300			
FINE AGG.	COARSE AGG. DFE300			

PETROGRAPHIC DATA (CRD-C 127):

	#72125	#72127
Quartz - - - - - -	85.4%	67.5%
Siltstone - - - -	2.4%	1.1%
Igneous Grains - -	1.4%	0.6%
Clay Lumps - - - -	9.7%	30.4%
Mica - - - - - - -	1.0%	0.4%
Organic Material - -	0.1%	trace

REMARKS

Sample #72125 is a bulk sample while #72127 is an auger sample through the entire stratum.

ENG FORM MAR 1968 5077-R

Issued Sept. 1973

STATE Ky.	INDEX NO.: 31	AGGREGATE DATA SHEET	TESTED BY: ORDL
LAT. 37	LONG. 88		DATE: May '72

LAB SYMBOL NO.: 72126 TYPE OF MATERIAL: Blending Sand

LOCATION: Dubuque Pit near Ledbetter off of U.S.60 overlooking the Ohio River

PRODUCER: Dravo-Groves-Newberg, Contractor

SAMPLED BY: Nashville Dist. C.ofE. personnel

TESTED FOR: Smithland L&D

USED AT: Barkley Dam

PROCESSING BEFORE TESTING:

GEOLOGICAL FORMATION AND AGE

GRADING (CRD-C 103) (CUM. % PASSING):

SIEVE	3-6"	1½-3	¾-1½	#4-¾	FINE AGG.
6 IN.					
5 IN.					
4 IN.					
3 IN.					
2½ IN.					
2 IN.					
1½ IN.					
1 IN.					
¾ IN.					
½ IN.					
⅜ IN.					
NO. 4					
NO. 8					
NO. 16					
NO. 30					
NO. 50					90.4
NO. 100					27.7
NO. 200					2.3
-200 (a)					
F.M. (b)					

(a) CRD-C 105 (b) CRD-C 104

TEST RESULTS

	3-6"	1½-3"	¾-1½	#4-¾"	FINE AGG.
BULK SP. GR. S.S.D. (CRD-C 107, 108)					2.60
ABSORPTION, % (CRD-C 107, 108)					0.7
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)	—	—	—	—	1
SOFT PARTICLES, % (CRD-C 130)					—
% LIGHTER THAN SP GR ____ (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT AV % LOSS, 5 CYC $MgSO_4$ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING ____					
UNIT WT, LB/CU FT (CRD-C 106)					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC HEAT, BTU/LB/DEG F. (CRD-C 124)					
REACTIVITY WITH NaOH (CRD-C 128): Sc,mM/L:					
Rc,mM/L:					

MORTAR-MAKING PROPERTIES (CRD-C 116)

TYPE ____ CEMENT, RATIO: ____ DAYS ____ %, ____ DAYS ____ %

LINEAR THERMAL EXPANSION MILLIONTHS/DEG F. (CRD-C 125, 126):

ROCK TYPE	PARALLEL	ACROSS	ON	AVERAGE

MORTAR:

MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):	FINE AGGREGATE 2 MO.	6 MO.	9 MO.	12 MO.	COARSE AGGREGATE 3 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT. % Na_2O EQUIVALENT:								
HIGH-ALK. CEMENT. % Na_2O EQUIVALENT:								

SOUNDNESS IN CONCRETE (CRD-C 40, 114):

			F&T	HW-CD	HD-CW
FINE AGG.	COARSE AGG.	DFE_{300}			
FINE AGG.	COARSE AGG.	DFE_{300}			

PETROGRAPHIC DATA (CRD-C 127):

Quartz - - - - - - - - - - - - 86%
Siltstone - - - - - - - - - - 8%
Igneous Rock Fragments - - - 4%
Weathered Rock Fragments -- trace
Mica - - - - - - - - - - - - - 2%

REMARKS:

ENG FORM MAR 1965

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1.AGENCY USE ONLY *(Leave blank)*

2.REPORT DATE
January 1998

3.REPORT TYPE AND DATES COVERED
Final report

4.TITLE AND SUBTITLE
Investigation of Concrete from I-20 Near Monroe, Louisiana

5.FUNDING NUMBERS

6.AUTHOR(S)
G. Sam Wong

7.PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

8.PERFORMING ORGANIZATION REPORT NUMBER
Miscellaneous Paper SL-98-1

9.SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11.SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a.DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b.DISTRIBUTION CODE

13.ABSTRACT *(Maximum 200 words)*

This report covers an investigation conducted in 1994-1995 to determine the probable cause of concrete pavement deterioration in certain lanes of I-20 east and west of Monroe, LA. The investigation was conducted by the U.S. Army Corps of Engineers Waterways Experiment Station at the request of the Louisiana Department of Transportation. Cores taken from distressed and non-distressed areas from different sections of the roadway were evaluated to determine the following: (a) the role of alkali-carbonate-rock reaction; (b) the role of alkali-silica reaction; (c) the contribution of freezing-and-thawing action to the deterioration; and (d) the contribution of fresh concrete properties and construction practices to the deterioration. The report includes the results of these analyses as well as conclusions and recommendations.

14.SUBJECT TERMS
Concrete
Concrete pavement

15.NUMBER OF PAGES
80

16.PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	18.SECURITY CLASSIFICATION OF THIS PAGE	19.SECURITY CLASSIFICATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102